NEWTON

3D Multimedia Lab for Exploring Physics

Mechanics

Quick Users Guide

DesignSoft
2006

Contents

1 Introduction

The virtual world of Newton v3.0 provides a completely new way of learning physics–the exploration of kinematics and dynamics on a computer in 3D. The virtual world of Newton is ruled by the simulated laws of physics, allowing you to build, manipulate and investigate your experiments interactively, without the limitations of physical models.

When creating an experiment in Newton, you can select from a wide range of real world or abstract objects, from the simplest geometrical bodies (brick, sphere, etc.), complex instruments (stands, slope, car, etc.), and constraints (many types of joints and springs). You can adjust their physical parameters (mass, elasticity, friction, etc.); assign to them forces, torques or velocity; and make relationships subject to constraints. You can add virtually any object to Newton using a VRML editor; you may also export your experiments in VRML format.

With the example files included, it's easy to get started. You can alter them and simulate again, and you will see that it's quite simple to create amazing demonstrations.

When running a simulation, the bodies start moving, guided by the acting constraints; are rotated by torques; and collide with each other as in a movie. Actually, you can set up one or more "cameras" and capture their views of the experiment, storing them in an AVI file.

You can also add descriptions to your examples, with explanatory texts, images, and formulas. Using diagrams, it's easy to measure and evaluate the results of your experiments. Several user-defined curves can be displayed on the same diagram, so it's easy to compare the measured data with the results derived from theoretical calculations. You may also change the units of the physical quantities.

This quick start manual is only a short excerpt of the detailed documentation, which can be found on the CD.

2   Installation

2.1   Installation Procedure

Minimum hardware and software requirements

- IBM PC AT/486DX or compatible (Pentium or better recommended)
- 128 MB of RAM
- A hard disk drive with at least 100 MB free space
- CD-ROM
- Mouse
- 24 bit true color, fast VGA graphics card with OpenGL Support
- Microsoft Windows 9x / ME / NT / 2000/ XP
- Novell Netware version 3.12 or later or MS Windows NT/ 2000/ XP Server or later for the Network versions

If the program is copy protected by a hardware key, the minimum hardware configuration includes also a parallel printer or USB port.

Installation from CD-ROM

To begin the installation, simply insert the CD into your CD-ROM drive. The Setup Program will start automatically if the Auto-Run function of your CD-ROM has been enabled (Windows-Default). If not, Select Start/Run and type:

 D:SETUP (Enter) (where D represents your CD-ROM drive).

The setup program will start.

Note: This software may come with copy protection. For further details see the Copy Protection and the Network Installation sections.

Following the Installation Steps

NEWTON's Setup Procedure follows the steps standard with most Windows Programs. There are several screen pages where you can enter or change important installation choices, such as Type of Installation, Destination Directory, etc. To continue installation, click on the **Next** button. You can always step back, using the **Back** button. If you do not want to continue installation for any reason, click on the **Cancel** button. If you elect to cancel installation, the program will ask you if you really want to exit. At this point you can either resume or exit Setup.

Welcome and Software License Agreement

To begin the Procedure, click on the **Next** button on the Welcome Page. The first step is the Software License Agreement.

Note: By clicking on "Yes" you are agreeing fully with DesignSoft's Terms and Conditions for using this software.

Entering User Information

This data is used to personalize your copy of the software. By default, the installation program picks up the data entered when you set up Windows. You accept these names as defaults by clicking on Next or you can change them.

Depending on your program version you might also need to enter a Serial Number located on your CD-ROM package or on your Quick Start Manual.

Choose Destination Location

Here you can select an Installation Directory other than the one suggested as a default. The default is the Windows Standard Directory for Programs. To change the directory, click on Browse and select a different drive and/or directory from the Choose Folder Dialog.

Note: If you are installing NEWTON for Windows to a hard disk that already has an earlier version of NEWTON, you must be sure to use a new directory name for NEWTON for Windows, such as the suggested directory, C:\Program Files\DesignSoft\Newton, or the working files you have already created will be overwritten and lost. If uncertain, exit setup, copy your NEWTON files safely to another hard disk directory or to floppy disks, then resume setup.

Completing the Setup

After all the selected files have been copied and the Start Menu entries created, you are asked if you want to place a Shortcut to the NEWTON program file on your Desktop. The last page indicates a successful installation and invites you to open and read a file with the latest information about NEWTON. We urge you to take a moment and review that file. Click on finish when you're ready.
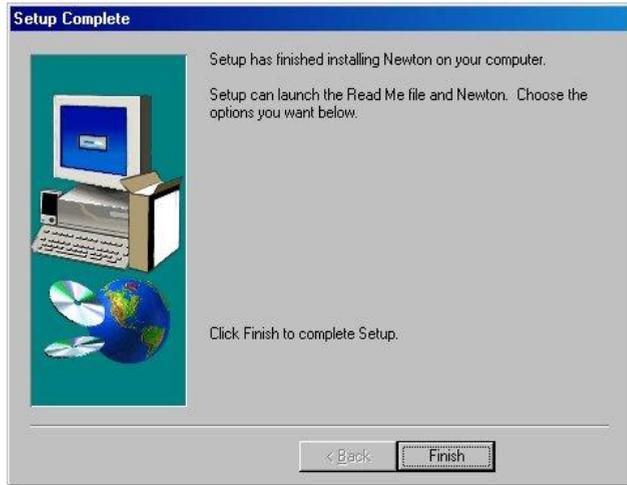
Note: You can read the latest information in the file again at any time by selecting Read Me from the Newton Start Menu Entries. You can also get the latest information about changes or new features by visiting our Web Site, www.designsoftware.com.

2.2 Uninstalling NEWTON

You can uninstall *NEWTON for Windows* at any time. Note that this will not delete files you have created.

1. To begin Uninstallation, choose **Newton for Windows** from the **Newton Start-Menu** Entries.

2. In the Window that appears, double-click on **Uninstall Newton**.

3. Click on *Yes* if you are positive you want to uninstall *Newton*.

After all the files have been removed successfully, an *OK* Button appears. Click on it and uninstallation is complete.

2.3   Network Installation

To install the Network version of *NEWTON*, you must log on to your server machine as a user with administrative privileges (Novell 3.x: supervisor, Novell 4.x: admin, Windows NT: Administrator). Then execute the procedure for the Hard Disk Installation on a disk volume that is accessible from the network. Now carry out the following additional steps:

Make all files in the program and user directories sharable:

> **Novell 3.x:**
>
> FLAG *.* S SUB
>
> **Novell 4.x:**
>
> FLAG *.* +SH /S
>
> **Windows NT/2000/XP:**

Depending on the setup of your system, you can give the rights to a group (<groupname>) whose members will then have the appropriate rights automatically.

Next make sure that the clients have a mapped drive set to the network drive containing the NEWTON program folder.

To assign (map) a drive letter to a network computer or folder do the following:

1.   Open Windows Explorer

2.   On the **Tools** menu, click **Map Network Drive**.

3.   In **Drive**, select a drive letter e.g. **G:**

4.   In **Path** (Win9x/Me/ or **Folder** (NT/2000/XP), select from the drop-down list or type in the network drive

(server and share name) or folder name to which you want to assign (map) a **Drive** letter. Note, that share name refers to a shared folder on the server. On Windows NT/2000/XP you can use **Browse** to find the network computer, drive and folder.

5. Set the **Reconnect at Logon** checkbox.

6. Press **OK**

7. **Examples:**

   Drive**: G:**

   Folder: *servername**sharename*

   or

   \\MyServer\Volume1

   \\MyServer\Volume1\Public

After you have set everything up on the Network disk according to the instructions above, you must run the setup program on each Novell workstation where you want to run *NEWTON*. Using the Run command, start **NSETUP** from the **Newton\NWSETUP** directory. Note, do not double click on the NSETUP icon, but use the Run command instead to start the program.

When you run NSETUP, you must specify the working directory (which should be located on a local drive of the workstation). **The working directory can be on the network; however in this case the path of this directory must be different on every workstation.** After you've specified the working directory, you may install the optional measurement hardware for NEWTON. After running *NSETUP*, you will be able to run *NEWTON* simultaneously on any number of workstations, just as though each workstation had a single user version.

2.4   Copy Protection

Software Protection

If your version of NEWTON is copy-protected by software, select **Authorize** from the **Help** menu. Refer to the CD insert or to the "Manual for Registration and License Control" for more information.

Hardware protection

If you have a hardware-protected version, plug the dongle (hardware protection key) into the parallel (printer) or USB port connector. If you have a printer, connect it through this key. Should you forget to connect the dongle, an error message will come up on the screen:

```
Hardware protection key is not present
```

> *Note: If you have a dongle-protected version under NT/2000/XP you should install Newton in Administrator mode and restart the computer after installation.*
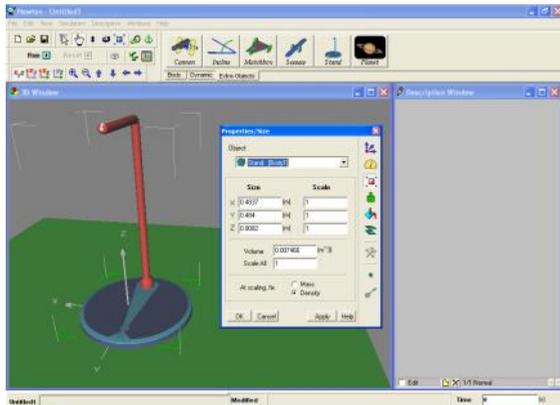
3   Overview

In this chapter we present NEWTON's screen format, controls and menu structure.

3.1   Screen layout

The user interface of the program is divided into six main parts:

    3D Window
    Description Window
    Toolbars
    Menus
    Status field
    Dialogs

On the left side of the initial screen you can see the 3D Window, where you can edit or track the ongoing experiments in a 3D perspective view.

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Use the ![camera bar icons] control buttons (Camera bar), to change your point of view. Rotate the scene, zoom-in or zoom-out, and select special top or side views. Even if a portion of the experiment is obscured from one vantage point, you can adjust the camera and bring it into view. You can also rotate the scene by holding down the left mouse button and moving the mouse, zoom in and out by holding down the right mouse button, or shift the scene by holding down both buttons and moving the mouse.

Using the ![scene bar icons] control buttons (Scene bar) and the mouse, you can modify objects and their positions in the 3D window. The first two icons choose between the geometric and physical editing modes. Using the geometric editing mode, objects can be moved freely without regard for their logical and dynamic relationship to the other objects. The Bodies can slide into each other without collision, and the constraint parameters can be altered using the mouse.

Using the ![hand icon] physical editing mode, the bodies collide and slide against each other, remaining on their track according to the constraints. The next three icons give you control over vertical position, object rotation, and zoom setting. The last two icons are used to build various relations among the object, link and anchor.

The right window (Description Window) presents explanations, pictures, or diagrams. Diagrams can display the curves of the experiment based on the simulated or theoretical results. The Description Window may also contain interactive elements, including buttons, edit fields, radio boxes, check boxes, or track bars. The Description Bar presents icons that you can use when editing or creating the Description Window.

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On the top of the application window you can see many toolbars. One of the most important of them is the **Object Bar.**
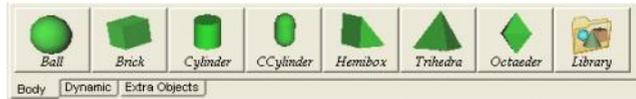
It contains the icons of the commonly used bodies, constraints and auxiliary objects that you can use in your demonstrations. The different types of objects are grouped on different tabs. Click on an icon to pick up the selected object and place it into the 3D window.
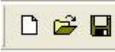
The toolbar helps you in performing file operations.

In some situations, pressing the right mouse button will bring on-screen a context menu to give you quick access to commonly used commands related to the selected graphical object or to the panel you clicked on. You can find these by right-clicking the objects in 3D Window or the graphical objects of the Description Window.

One of the most important dialogs, which you can access by right-clicking or double-clicking an object, is the Properties Window, where you can set or modify the attributes of the bodies and dynamic objects.

The tabs at the bottom-left corner of the main window also have a context menu, where you can quickly switch among the open demonstrations. In the bottom-right corner there is the Time field. It displays the elapsed (virtual) time of the running simulation.

3.2   Running demonstrations

Newton comes with many prepared example demonstrations.

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Select the File/Open command to load them.

When you load an example, the 3D and Description Windows will show the 3D experiment and the explanations (if any) respectively.

You can rotate the point of view by clicking on a blank area of the 3D Window, holding down the left mouse button, and moving the object to the desired position. If you click with the right mouse button, you can step back and forward. You can slide up or down in the space by moving the mouse and holding down both mouse buttons simultaneously.

Click on the ▶ (Run) icon to start the simulation. The simulated laws of physics will guide the bodies in their motion. To stop the simulation, click on the ■ (Stop) icon; it appears in place of the Run button when an experiment is running. You can reset the scene by clicking on the ⏸ icon.

The smoothness and speed of the motion depend on your computer speed and screen resolution. If a simulation requires a lot of calculations, and your PC's processor isn't fast enough, the simulation will not move smoothly. In this case, use the 👁 (Playback) function. It plays the last simulated demonstration smoothly and continuously from the PC's DRAM memory.

4   Getting started with examples

In this tutorial chapter, we will show you step-by-step how to use the program and how to make convincing experiments and demonstrations. We recommend that you take the time to walk through all the examples, not just read them.

The instructions for the first and second tutorials are detailed, while the later examples build on the knowledge acquired from these and are not presented as thoroughly.

4.1   Demonstrating free fall and making diagrams

Our first example is very simple: you are to investigate the movement of a ball constrained by the constant gravitational field of the earth. You will learn how to set the basic properties of the bodies and how to depict their movement via diagrams. Later, the measured data will be compared with the results derived from theoretical calculations. You can find this pre-built example in the Freefall.ex example file.

Create a new experiment by clicking on the $\square$ (*New*) icon. This will call up empty 3D and Description Windows and the screen shows only a tabletop.

Here's how to modify the point of view in the 3D space: to rotate the vantage point, click and hold the left mouse button on an empty area of the 3D Window and move the mouse in the selected direction. To step forward and back (zoom-in and zoom-out), press and hold the right mouse button. To slide in any direction, press and hold both mouse buttons. Note that you can do the same but in larger steps using the ⊕ ⊖ ⬆ ⬇ ⬅ ➡ toolbar controls.

Perhaps you'd like a special top or side view of the scene– use the ⬚⬚⬚ toolbar buttons to select another view, or the ⬚ button to revert to the general 3D view.

Using the ⬚⬚⬚⬚⬚⬚⬚ control buttons (Scene bar) and the mouse, you can modify objects and their positions in the 3D window. The first two icons choose between the **geometric** ⬚ and **physical** ⬚ editing modes. Using the geometric editing mode, objects can be moved freely without regard for their logical and dynamic relationship to the other objects. The Bodies can slide into each other without collision, and the constraint parameters can be altered using the mouse.

Using the ⬚ physical editing mode, the bodies collide and slide against each other, remaining on their track according to the constraints. For example, if a body is linked to a hinge, it can move only on a circular track. Because more editing can be carried out in the physical editing mode, it is the default. In the following instructions, you only have to switch to the geometric mode if requested.

Let's start building our first simple experiment.

You can find the body named "ball" ⬚ on the Bodies page of the Objects toolbar. Click on its icon and the body will immediately appear in the middle of the 3D area. To move the ball to its initial position, use the mouse as follows. To change the location, press and hold the left mouse button over the ball and move the mouse over the scene. This will move the body in the xy plane and keep the z coordinate unchanged. To place the body properly in the z direction, press down and hold the ⬚ icon and use the mouse.

The properties of the ball can be set in the Object Properties dialog. This window will appear if you double click on the ball.

The property window gives access to several pages of properties grouped according to function. For example, on the Location page the position and rotation can be changed, while on the Size page the size of the body can be reset. Each kind of object can have different panels. Clicking on the body invokes the default page, showing the material properties group. On the right side of the window there are icons which you can use to switch to another page of properties.

At the top of this window there is a combo box that contains a list of all the objects currently present in the 3D scene. If you would like to alter its properties, select an object by name and change the appropriate settings. In this list you will find, in addition to the object's name, its *identity*. All objects have a name and an identity, and they are not the same. The identity, as it identifies the object, cannot be used with more than one object at the same time. It is a combination of a short character string–generally an English word or abbreviation– and a number. There are restrictions: special character cannot be used, for example +-*/[]() or space. We will reserve these special characters for later use; for example, in defining curves in diagrams.

The name of the object can be anything; it can contain more than one word; and the same name can belong to more than one object.

You can easily change an object's name or identity. Click the right mouse button somewhere on the properties window and a context menu will appear with the command 'Rename'. Name the ball 'Rubber Ball'.

Click the icon to bring up the Material panel. There is a combo box on this page with commonly used materials. For material, select "Rubber" for now. There are other fields on this page–density, friction, elasticity, etc.–but we will accept their default values now. Press the Apply button to use these new settings.

The color of the ball can be changed on the ⚑ Appearance page. The ball in the picture below has been assigned a light blue color.

The dimensions of the body may be altered on the 🔲 (*Size*) page. Assign 10 centimeters to the diameter (radius equals 0.05 meters) in the first field of the *Size* panel.

To assign a mass to the body, bring up the 🏋 Inertia panel.
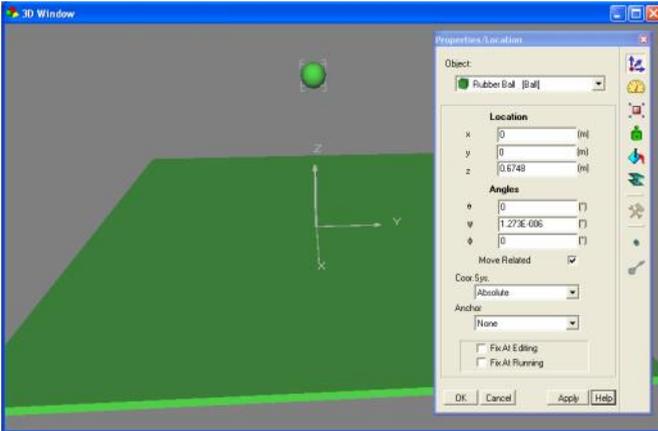
Click on the 🏋 (*Inertia*) icon and set the value of Mass to 0.8 kg. Note that since an object's mass is directly proportional to the density, the density of the ball is changed as well.

Using the 📍 (*Location*) panel, set the ball's position to (x=0,y=0, z=2) or z=2m. Adjust the scene by stepping back

using the 🔍 icon until both the ball and the table can be seen.

Start the simulation. Click on the ▶ (*Run*) button and watch the ball on the screen.

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After falling briefly, the ball bounces off the table. Note that the simulation doesn't stop by itself. To stop it, click on the ■ (*Stop*) button. Click on the ⏮ (*Reset*) icon to reset the experiment environment to its pre-simulation state.

Making diagrams

Now let's create diagrams to represent the motion of the ball.

In the middle of the table, a coordinate system indicates the origin of the 3D space. By default, the positions versus time diagrams are made using this coordinate (reference) system. The three gray axes that are drawn from the origin, perpendicular to each other, represent the three (x, y, z) directions in the space. In this example, we will display the position of the ball on the *z* axis as a function of time.

First, be sure that the Description window is in the Edit mode. This is the default for new projects, but you can always switch to Edit mode using the Edit checkbox at the bottom left corner of the Description window. When this window is in Edit mode, you should see the vertical Description toolbar with icons to help you create the contents of the window.

Find the (*Diagram*) icon and click on it to bring up the Diagram properties window. In this context, you could create a curve and place it in a diagram in the description window. But sometimes you want to just define an empty diagram to prepare for a curve that you will add later. Let's do that now.

Click the OK button. Place the diagram in the Description window as follows. After pressing the OK button, the cursor will assume the shape of a small coordinate system. First, move the mouse to the position where you want to place the top left corner of the diagram and click there. After this the diagram size will change as you move the mouse. Moving the mouse now will determine the bottom right corner of the diagram and if it is in its place, click with the left mouse button again.

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If you need to modify the size of the diagram, select the diagram by clicking anywhere within its area, and move the graphic cursor above one of the little marking squares appearing in the corners. Use the basic Windows mouse techniques to click and drag the marking squares to their required places. Lastly, you can move the whole diagram by clicking within the diagram area and dragging it with the mouse.

Now let's add a curve to the diagram. Double click on the diagram area, and the Diagram properties window will appear again. This is a two-page dialog. Clicking on the tabs at the top you can change between the pages **Curve** and **Appearance**. On the Curve page you can create, alter and delete curves, and on the Appearance page you can set the general appearance of the diagram, such as the scaling of the axes, format of numbers, etc.

Select the Curves tab to activate its panel. There are two different ways to define a curve. We will use the quicker and easier method, but its possibilities are limited.

Look for the tree view list in the upper part of the window. This presents the variable of the scene object in a tree-structure. Clicking on the ball displays its physical variables, and clicking on the position node expands the three components of the position vector. Select the z component and click on the Add button below. This will tell the diagram tool to draw the position z versus time. Click the OK button to apply this setting.

Starting the simulation again, we see Newton plot the vertical component of the ball's position versus time. The curve is a parabola, a parabola that corresponds to the motion of a body accelerated by the gravitational field. Note that this curve was created with data obtained using numerical methods.

Now let's add the same curve, only created by theoretical methods. This will let us compare the two methods. First, however, to make the theoretical curve, we have to use another method.

Bring up the Diagram Properties window again by double-clicking on the diagram. On the Curves page click the Advanced button. This removes the object tree view from the screen. Two text fields and some new buttons appear. These two text fields show the variables assigned to the axes.
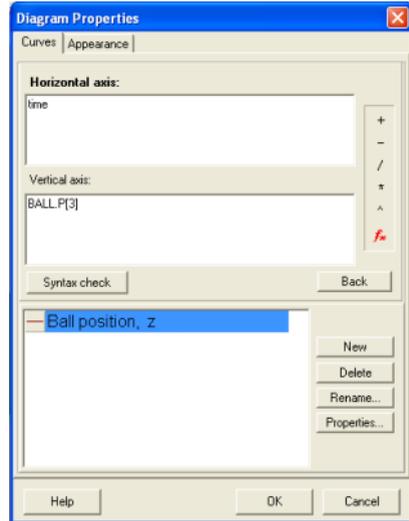
Select the previously created curve ("Position z") and note the simple expressions in its edit fields. In the previous step, where we selected the z-position of the ball, we have generated the curve by actually filling in these expressions. Before creating more curves let's study the properties of this existing curve.

The Edit fields of this dialog are called Horizontal axis and Vertical axis. In each field there is an expression already; „time" in the Horizontal axis and Ball.p[3] in the Vertical axis field. When the simulation is running, these two expressions are evaluated at every time step, and the two values together provide the point of the curve.

The 'time' expression is a global variable of the simulation; it defines the elapsed time from starting. The ball.p[3] expression is a reference to the z component of the ball's position. Here the 'ball' is the identity of the scene object we are examining, 'p' means the position of the ball and '[3]' means the 3rd (z) component of the position vector.

All the other variables of the bodies and other objects can be used; moreover, you can use mathematical functions.

You don't have to remember all the available expressions and variables of your experiment. If you click on the f_x icon, a dialog listing all the available and appropriate variables and functions will appear. You can browse and insert them into the edit field by pressing the Insert button.

Now we are finally ready to make a new curve. Click on the **Add** button and write into the fields the expressions shown in the figure below.


The word 'time' defines the horizontal axis variable to be the simulation time. The vertical axis is assigned the expression

2-(9.81/2)*time^2, written as the equation $z = z_0 - \dfrac{1}{2} \cdot g \cdot t^2$

in Newton. The term $z_0 = 2$ is the initial position of the ball.

Now we'll change the color of the first curve we created. Select this in the Curve list and click on the Properties button, which can be found in the right bottom part of the window. Set the color to Red and the width to 3.

Close the windows and run the simulation again.
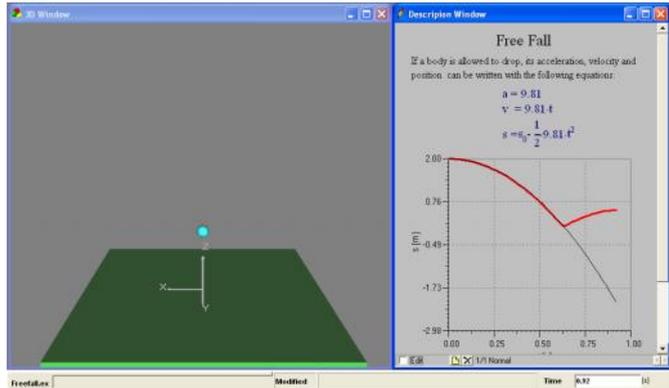
While the ball free falls to the table, the two curves overlap, as you can see in the picture.
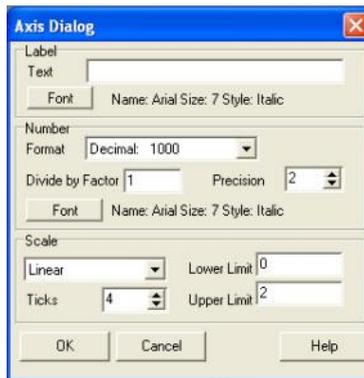
To set the axis properties, double-click an axis and work in the axis properties dialog that pops up. For example, adjust the upper limit of the time axis to 1.6, and then close it using the OK button.

You can prevent the simulation from running continuously. In the Simulation menu, locate the Time settings… command and click on it. In the window that opens, you will see the Period panel. Set the "final time" checkbox on and set the time to 1.5s.

4.2   Force and velocities

In this chapter you can learn how to add constant forces to a body, how to adjust them using the mouse in the 3D window, and how to assign an initial velocity to the body. This experiment can be found in the file named 'Const_Force.ex'.

Create a new example and place a ball on the scene by clicking its icon on the Object Toolbar. Move the ball to one of the table's corners by double-clicking on the ball and setting its position value on Location page of the Properties window. Type these values into the position fields:

<div align="center">x=1m, y=1m, z=0.5m</div>

Set the ball's color to blue on the Appearance page. Set the z component of the velocity on the Velocity page to 2m/s.

To verify the entries, click the check button under the edit fields to show the velocity arrow in the 3D Window. You can immediately see in the 3D window that the ball now has a red arrow emanating from the body's center of mass.

There's a more intuitive way to adjust the initial velocity. Using the mouse, select the vector then click on the vector's head by pushing the left mouse button. This will let you set the vector's direction. If you click on the vector's shaft, you can change its magnitude.
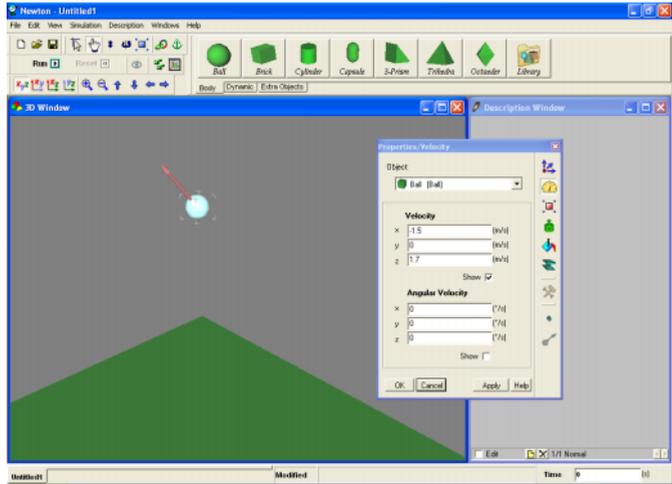
When you need to set a property to an exact value, use the Properties Dialog. Now let's set the velocity to x=-1.5, y=0, z=1.7 m/s.

Next, we will add calibration ticks to the curve of the ball's motion. Right click on the ball and in the context menu choose the Show/ Track / Points command. Now the body will leave markers along its path so we can examine the trajectory.

Start the simulation. The ball falls to the table in a parabolic arc, bounces up, and after a few more bounces falls off the table. Stop the simulation ■ and press reset ◀ to get back to the initial state.

Clicking the 🖘 (Force fields) icon brings up the Force Fields window. Here you can set all the external forces acting on the body: gravitational force, Coulomb force, and fluid resistance. It can be seen that gravity is set to constant acceleration and its value is $9.81\,m/s^2$ as on the surface of the Earth. We will use this value in all our examples.

Try the experiment with gravitation set to "none". Click on the OK button and see what happens. The ball will move along a constant line with constant speed, and won't fall to the table.

Stop the simulation and return to the original state by clicking on the reset button. Now we will add a constant force acting

on the ball. Select the body and click on the force icon on the dynamics tab of the Object toolbars. In the 3D window you can see the blue force vector originating from the body's center of mass. You can alter the force vector in the same fashion as seen earlier with the velocity vector. Click on the tip of the vector to set its direction, and click on the shaft to set the strength of the force.

Add one more force to the body
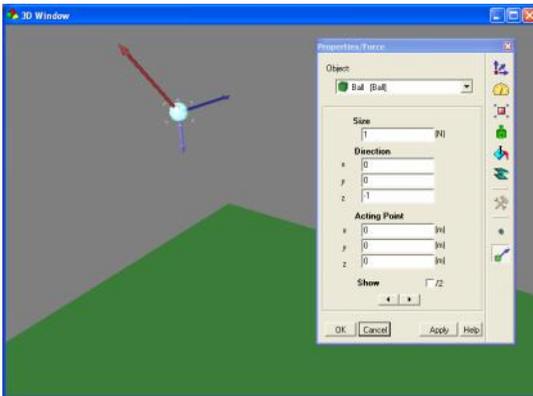
Double-clicking on the Force's blue arrow brings up the Properties dialog. From this dialog, you can set the force's parameters. Set the two constant forces with the help of this panel. The first vector should be a force of 1N, and its direction x = 0, y = 0, z = -1, pointing downwards. The second vector's force should be 2N, and its direction x=1, y=0, z=0, (horizontal).

Start the simulation and observe that the body's velocity is changing linearly, indicating a constant acceleration. The body's motion will stay in a planar zone, because there is no velocity or force in the y direction.

Let's make some diagrams of the vertical component of the motion. Click on the Diagram icon on the Description window toolbar. The diagram dialog appears so that you can define curves.
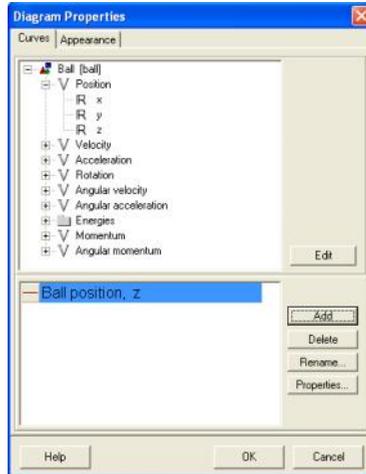
Choose the Ball/Position /z node and click the New button. This defines a new curve that will draw the z component of the position versus time. Click on the OK button and place the diagram on the Description Window. You can change the axis settings of the diagram by double-clicking.

To compare a theoretical curve to the curve calculated by Newton, you can draw the analytical and the numerical results on a single diagram. First, we'll solve for the analytical solution of this problem.

There is no gravitational force, so only the two constant forces accelerate the body. Since the bigger force doesn't contain a component in the vertical (z) direction, we need only take into consideration the smaller force. Restating the problem, the $F_z = -1(N)$ force component acts on the body and accelerates it in the z direction. The object has $v_z = 1.7 \,(\text{m/s})$ initial velocity and $z = 0.5 \,(m)$ initial position (we set these parameters earlier).

According to Newton's second law ($F = ma$), the acceleration is:

$$a = F/m = -1\,(N)\,/\,0.1\,(kg) = 10\,(m/s^2)$$

Next, we need the expression that describes the position versus time function of an object with constant acceleration. This is the function:

$$s = \frac{1}{2}\,at^2 + v_0 t + s_0\,,$$

Substituting the values:

$$s = -5\,t^2 + 1.7\,t + 0.5$$

Put a curve for this equation on the diagram. Click twice on the diagram area (not on an axis or curve, because then the axis or the curve dialogs will appear). In the diagram properties window click on the Advance button. The upper part of the window will change, the object tree view disappears, and the two edit fields appear for directly defining the expression to the diagram.

If you click on the curve created earlier you will see the two expressions of that curve. You need to place the new expressions. Click on the new curve, and write in the horizontal axis edit field:

time

And in the vertical axis edit field:

-5*time^2+1.7*time+0.5,

This format is required for Newton. The format below is perhaps more familiar, but they both define the same equation, $-5\,t^2 + 1.7t + 0.5$ equation.

Change the attributes of the earlier curve to differentiate it from the new curve. Select the curve and click on the **properties...** button. On the Curve dialog set the color to yellow and the width to three.

Close the dialogs and start the simulation. If everything has been done correctly, the theoretical curve and simulation curves will exactly overlay each other.

4.3   Fix Joint

In Newton, it is possible to fix two or more bodies rigidly to each other. Now the bodies must move and rotate together and share an aggregate mass and inertia. The motion of this assembly is very similar to that of a simple body except that the material properties of the two bodies can be different. Consider two cubes with different friction coefficients. Put the cubes on the table and push, Repeat with the other cube's surface facing downward. Note that the friction force will be different depending which side is in contact with the table.

In this chapter you will learn how to build a gyroscope from a brick and a capsule rigidly fixed together. The dynamic object you thus create will be called Fixjoint.

1. Get the brick and capsule from the Object bar and place them in the scene. Change their color– the capsule to red and the brick to light blue.

2. Resize the bodies. The diameter of the capsule should be 0.03m, its length 0.3m. The side of the brick should be x,   y   =0.4m, z=0.03m.

3. Get a FixJoint from the object bar and place it on the 3D window.
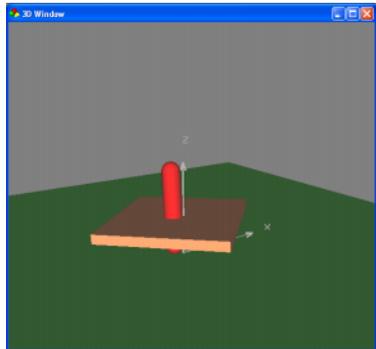
4. Select the three objects with the mouse and press down the (Link to…) icon. This causes the two bodies to be linked to the Fixjoint. The position of the FixJoint will be the center of mass of the two bodies.

5. In Physical mode, dragging either of the two objects drags the other with it. The two bodies' relative position to each other can only be adjusted in geometric mode, so click on the geometric icon. Position the two objects according to the picture below.

6. Assign an initial velocity to the gyroscope. Since the bodies don't have independent velocity, only collective, their velocity cannot be altered individually on the Properties window. The collective velocity can be changed on the FixJoint Properties window, at the velocity page. Set to (-60,10, 750) -re. Their first two values mean a small change in the exact rotation around the z-axis, which makes the motion of the gyroscope more interesting.

7. Start the simulation.

4.4   Experiments with spring

In this experiment, a force acts on a body via a (linked) spring. The force of the spring model in Newton is composed of two parts; the first is a linear force in elongation that wants to stretch the spring back to its unstrained length. In the second term the force overcomes friction and is proportional to the velocity of the body. Expressed in an equation:

$$F_s = -D \cdot \Delta x - b \cdot v$$

Here Δx is the difference of the actual length and the unstrained length, D is the stiffness, v is the velocity, and b is the friction coefficient.

The behavior and use of the spring object will be explained in two examples. In the first, we attach the spring to a stand and link it to a ball to examine harmonic oscillation.

1. Place a spring ![spring icon] and a ball ![ball icon] on the scene clicking the appropriate icons of the object toolbar.

2. Select both the spring and the ball at the same time, and click on the ![icon] (Link to...) icon. This links the spring to the ball. Note that you can select two objects at the same time by selecting the first then clicking on the second while the CTRL button is pressed on the keyboard.

3. To set the parameters of the spring, double-click on it and work within the Properties Window that appears. Set the Stiffness of the force to 35N/m, and the unstrained length to 0.4 m.

4. Change the Location page of the properties window by clicking on the ![icon] (Location) icon. Adjust the z component of position of the spring to 0.8 m.

5. Place the ball under the spring and lift the ball up. You can do this by pressing down the ![icon] (move up/down) icon. This constrains the ball movement to up and down only.

6. Go to the inertia page of the properties window and set the mass of the ball to 0.5kg.

7. Start the simulation by pressing down the ![icon] button.

Notice that the end of the spring that is not linked stays in rest during the simulation.

Let's include a stand in our experiment.

8. Place a stand from the Object toolbar ![stand icon] on the scene.

9. Drag the spring under the Stand and lift it up until it touches the bar of the stand.

10. Anchor the spring to the stand. Select the spring. Then click on the ⚓ icon and then on the stand. Moving the stand now will drag the spring with it. To cancel the anchor, first select the body, then press down the anchor icon, and click anywhere on the background of the scene. You can also work with anchors from the Location page of the Properties window.

11. You can change the width of the spring. Press down the ▣ icon and move the cursor to the spring. Adjust the spring width by moving the mouse up or down. Note that this changes only the appearance, not the mechanical behavior.

12. Start the simulation with the ▶(Run) button.

The default setting of damping is zero–there is no damping. You can set the damping coefficient from the spring page of the properties window by double clicking on the spring. Try the value 0.1
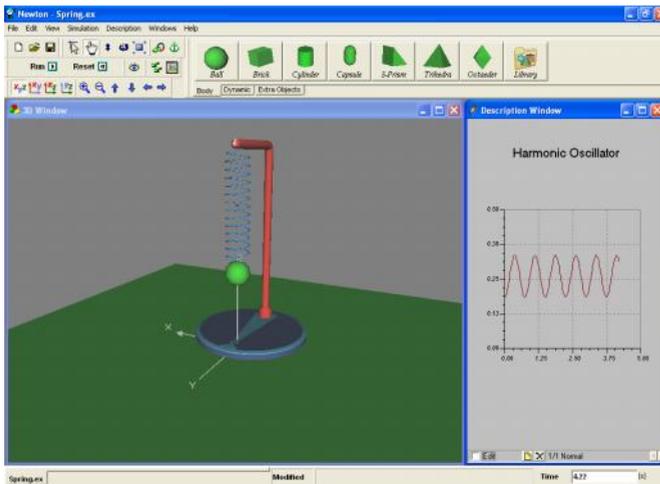
The unstrained length of the spring can be set while viewing the 3D window. Lift the ball to the desired unstrained position, click on the spring with the right mouse button, and select the unstrained length command from the context menu. This results in the actual size of the spring also being the unstrained size.

The following example is more complex, using three balls and three springs. (Springs_with3ball.ex)

1. Create a new example and place three balls and three springs on the table.

2. Set the mass of all three balls to 0.1kg and the unstrained length of the springs to 0.6m
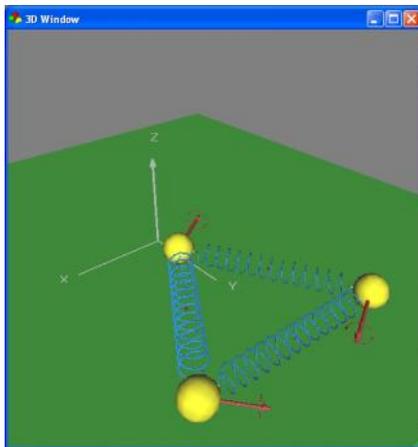
Link the balls to the spring as illustrated in the screen shot to the left.

3. Start the simulation.

In this example the ball-spring system is symmetric. You can adjust the unstrained lengths and the masses to try variants of this example.

4.5 Movement along a straight line

Frequently we will want to examine problems where motion is confined to one dimension. There is a constraint in Newton that reduces the six-degree of freedom case to only one. This object is a constraint called **Slider**. It will force the object to stay on a straight line.

If we link two bodies using a Slider, they will move together except for the distance between them, which can change freely. It is as though the bodies are skewered on a shaft and can only slide along its axis.

This constraint is well suited to an examination of one-dimensional motion. In this example, a ball and spring will permit us to examine the one dimensional harmonic oscillation.

Let's get started making an example (1DSpring.ex).

1. Place a ![Ball] ball and a ![Slider] slider on the scene.

2. Select the ball and change its color to red on the ![icon] (Appearance) page of the Properties window.

3. Select both the slider and the ball and click on the ![icon] (Link to…) icon, to put the ball on the constraint.

4. Place another ball on the scene and change its color to yellow.

5. Increase the mass of the yellow ball to 2 kg on the ![icon] (Inertia) page of the Properties Dialog.

6. Link the ball to the slider; select both and click on the ![icon] (Link to…) icon.

7. Place a ![Spring] (Spring) on the scene and link its ends to the two bodies (Select all together and click ![icon] icon).

8. Set the friction coefficient of the bodies to zero.

9. Start the simulation (![icon] Run).
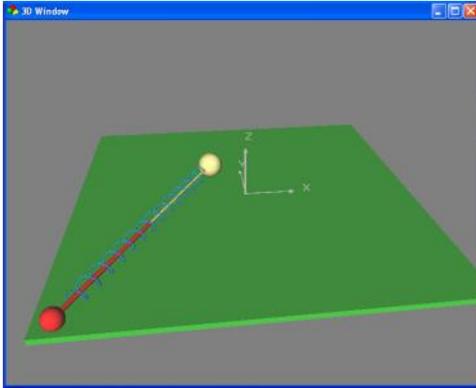
Explore this experiment by stiffening the spring (see the chapter 'Experiments with springs').

4.6 Circular motion

The dynamic object called Hinge constrains the body to move in a circular track. If we link two bodies to the hinge, we have modeled the linkage used for the rear wheels of cars.

Let's build a pendulum utilizing the hinge. (Pendulum.ex).

1. Retrieve a ![Stand] stand, a ![Ball] ball, and a ![Hinge] hinge from the Objects bar.

2. Lift the hinge to the end of the stand's horizontal shaft.

3. Anchor the hinge to the stand. Select the hinge, click on the ⚓(Anchor to…) icon and immediately click on the stand.

4. Select the ball and the hinge and click on the 🔗 icon to link them.

5. Switch to geometric mode and adjust the length of the hinge rod by lifting the objects.

6. Return to physical mode and set the initial angle of swing.

7. Start the simulation ( ).
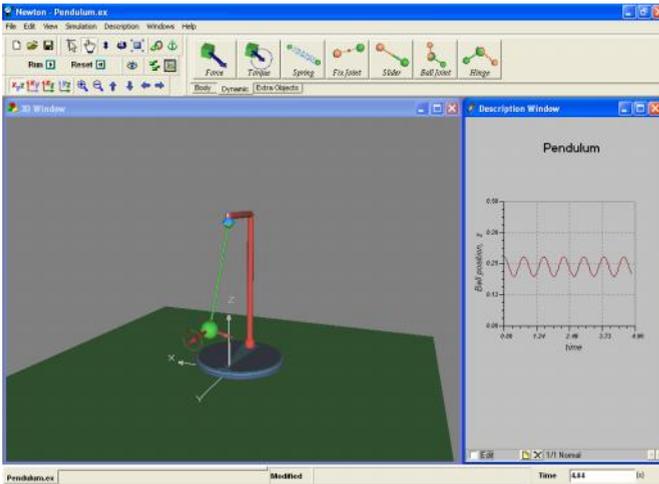
Go to the Properties window where the hinge's parameters are set. You can draw any of these parameters on a diagram, and they all can be reached from the Diagram dialog. In the diagram window above we have presented a curve showing the angle of swing of the pendulum.

4.7   Motion on spherical surface

You can constrain a body to the surface of a sphere by linking the body to a balljoint. A balljoint constrains the ball to remain at a constant distance from a point; however, the body can rotate freely around the joint.

We can make another pendulum, this time using the balljoint (Pendulum_withballjoint.ex).

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1. Place a stand, a ball and a balljoint from the object toolbar onto the 3D scene.

2. Select the balljoint, click on the ⚓ (Anchor to...) icon, and immediately click on the stand.

3. Select the balljoint and the ball and click on the 🔗 to link them together.

4. Switch to geometric mode to adjust the position of the ball. Place it under the balljoint.

5. Switch back to physical mode and drag the ball to its initial position.

6. Set the initial velocity of the ball. If you don't do this, the swinging ball moves in a plane. Now we want the plane of the swinging ball to rotate. To achieve this, assign a velocity to the ball perpendicular to this plane.

7. Start the simulation by clicking the ▶ (Start) icon.

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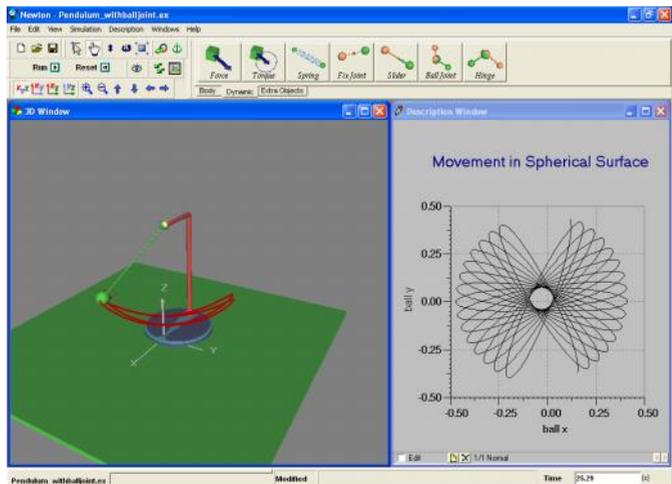
From the Properties Window, you can set all the balljoint parameters to exact values. Any of these parameters can be plotted as curves on the diagram. The picture above graphs the ball's position in the x–y plane.
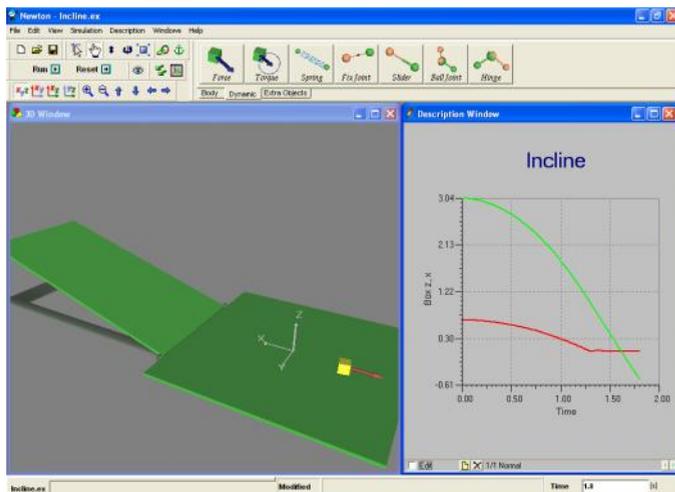
4.8   Incline

Extra objects consist of simple bodies and dynamic objects, which often appear in experiments. You will find these on the object bar. The incline is such an object. It consists of a rectangle, a hinge, and an incline-base. It has its own Object Properties window where the angle, the friction coefficient, and elasticity of the incline can be set.

Let's build an example using the simple incline (Incline.ex).

1. Click on the icon ![Incline] in the Object toolbar.

2. Set the table next to the incline in such a way that objects rolling down the incline will land on the table.

3. Set the angle of the incline by moving the flat of the incline.

4. Add a brick to the experiment.

5. Change its color from the (*Appearance*) panel.

6. Pull the brick up the incline until its bottom surface fits onto the surface of the incline perfectly.

7. Set the friction coefficient. Click twice on the body, the incline and the Table, set the values required on the Object Properties window.

8. Start the simulation by clicking on the (*Start*) button.

4.9 Planetary Motion

Up to now we have only made experiments in the gravitational force field of Earth. Using Newton, it is possible to set the gravitational field so the bodies attract each other according to Newton's gravitational law, $F=G\dfrac{m_1\,m_2}{r^2}$ This will allow us to demonstrate planetary motion. In this chapter we will show the detailed steps required to simulate our Solar system (InnerPlanets.ex). This simulation is quite different from those seen up until now, because the values of distance coordinates and time magnitudes are vastly larger. Try to imagine the huge distances that separate the planets, and the time scales of their periods. The main task in creating this experiment is to set the magnitudes of time and space parameters.

1. Create a new example and set the table visibility parameter to false.

2. Click twice the background of the 3D window, in an open area. The Properties window appears–select the starry night sky.

3. Set the *Dimension* value to 10^{12} (type: 1e12) in the View menu *3D window settings* [icon] dialog. This setting affects mouse movements in the 3D window. Bigger values make the same mouse movement cover far greater distances in the virtual space. You can travel millions of virtual kilometers with a single mouse gesture.

4. Set the gravitational force to planetary in the [icon] Simulation menu *Force fields* dialog.

5. Change the unit system to astronomical by selecting it from the combo box in the Simulation menu **Units** dialog.

6. In the Simulation menu Setting… command invoke the Settings dialog, set the virtual time to one day, and the time step to 0.01 day.

7. Click on the [icon] (Planet) icon in the extra objects tab on the object bar.

8. Select the sphere object, and double click on it to bring up the Properties Window. Choose one of the planets or the sun from the *Object name* combo box. Newton automatically sets the astronomical body's real properties.

9. Insert as many objects as you want (don't forget the Sun), repeating the previous step.

10. The two trackbars on the Properties window are useful for scaling the size of the Sun and the planets. Note that this scaling doesn't alter the mass or the density parameters. It's meant only for improving the view of the solar system.

11. On the bottom of the panel you can set the Date, which will affect all of the object positions.

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12. Choose a good location in the universe where you can see all the objects, and run the simulation.

> *Note: During editing in this experiment, it is possible to inadvertently get inside an object while moving the camera, Of course we can't find that object because from the inside it is transparent. If this happens, use the camera positioning controls or the camera properties window to get out of the object.*
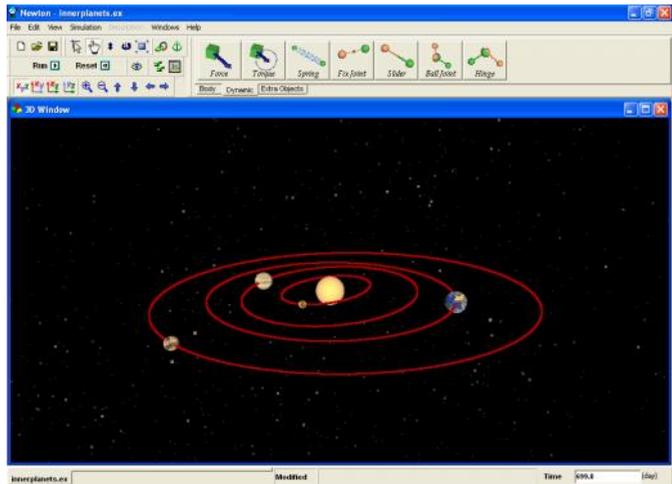
4.10 Problems

This chapter shows how to start with an existing example file and transform it into a new problem file.

Just as with example files, problem files contain 3D window(s) in which the problem is illustrated, and description windows. Problems can be presented using both types of windows. You may also use the description window to

present some hints or even a solution to help the problem-solver.

We will now alter the free fall example into a problem. The task for the student will be to answer a few questions. Follow the steps below:

1. Open the Freefall.ex file.

2. Delete all the text except the title.

3. Place this text below the title :

```
'A body is dropped from a height of 2 meters.'
```

4. In the first question (problem a) the student has to choose the right value from the possible answers. The text of the question is:

```
Find the acceleration of gravity on the earth!
```

We'll use ⊙ *a* ⊙ *b* (*radio buttons*) to make this a multiple-choice problem. You will find radio buttons on the description toolbar. Place one on the description window and double click on it. The radio button properties dialog appears with which all the settings can be adjusted. Enter three answers into the row list: 2, 9.81, 100. One of these has to be the right answer. You must tell the program which answer is correct. Select the **Right value** field and write the line number holding the right value. Newton permits you to calculate scores–an important feature when you create a set of problems.

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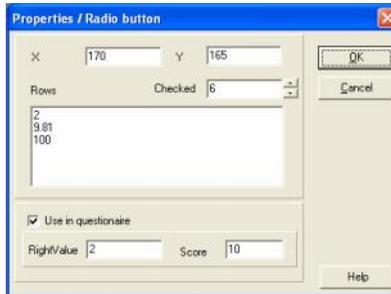
5. The second question (problem b) will be the calculation of the time the ball takes falling to the floor. The problem text is:

```
Find the time when
 the ball reaches
    the floor!
```


Use the ![ab] (*editfield*) element for this kind of problem. Click on the icon in the toolbar, put it into the description window, and click twice on it. In the properties window, chose the **Use in questionnaire** option to enter the right value (0.64 second in this problem), and assign a tolerance of 0.03. (This means that the acceptable error is $0.03/0.64 = 5\%$). Finally, enter the point value for scoring this problem.
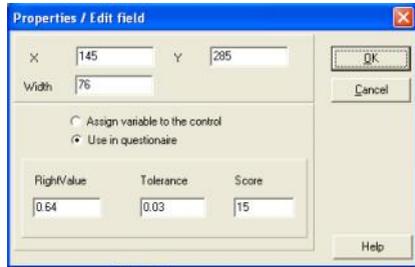
6. The third task (problem c) is to solve a yes-no question. The problem text is:

```
If the answer is right, check the box!
```

7. For this multiple choice test, the best descriptive element is the checkbox component. Click on the ![X] icon on the toolbar and place it onto the description window.

Let's give this a caption that asserts a questionable truth. Click twice on the checkbox and its properties window will appear. Enter the caption:

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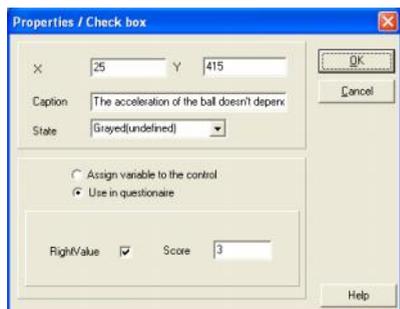
```
The acceleration of the ball doesn't depend upon
                    its mass.
```

Check the right value of this statement to true, and enter the point value for scoring this problem.

8. It is possible to give hints to help the student solve the problem. Click on the 🗋 (*Create new Page*) icon at the bottom of the description window. Each time you click on this icon, a new page is created. It is possible to delete the page currently on-screen with the ✖ (*Delete Actual Page*) icon. You can move among the pages with the ◀▶ icon. To tell Newton that the page contains a hint, you have to change the type of the newly created page. Click on the description window with the right mouse button and in the context menu choose *Set page as/Hint* command. Newton's scoring system allows you to define a penalty when a student needs a hint. His/her score will be reduced by a given percentage. To set this number, click on the description window with the right mouse button, and choose the *Hint Score Reduction...* command in the context menu.

9. It is also possible to provide the full solution. However, if the student looks at it, her score on this problem is set to zero. Create a new page 🗋, write the solution, and right-click on the description window. In the context menu choose *Set page as/Solution* command.
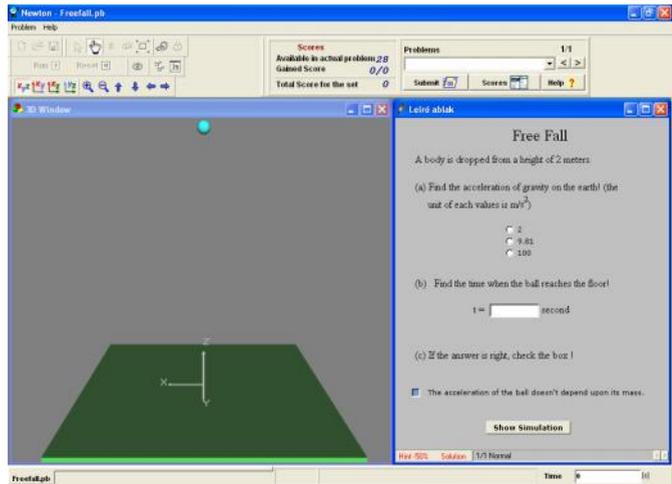
10. When you have completed the problem file, you can save it. In the Save dialog, change the filter of the file type to '*Newton problem file *.pb*'.

When you next reload the file, Newton will determine automatically that it is a problem file and switch to problem solving mode. All editing operation will be prohibited and in place of the Object bar, Newton will present the Problem control. The student's answer can be entered for the interactive elements, and hints and solutions can be fetched using the two buttons of the status bar of the description window. To test a value entered by the student, click on the Submit button on the problem tool bar.

To switch back to editing mode, click on the Problem menu Edit command. Entry to the Edit mode is password protected so that students will be prohibited from checking their answers or otherwise manipulating the test. For all problems there is only one password. Its default value is 'Newton', and, of course, you can change it. If you forget your password, reinstall Newton (be careful not to overwrite your own

experiment and problem files) to set the password again to the default.

If you have a number of problem files covering the same material, you can bind them into a *set* of problems. The resulting problem set can be used for student testing. You can do this clicking on the *File/Problem Set   Manager...* command, which will invoke a dialog where you can set up the details for the problem set. The extension of a problem set file is '*.pbs'.