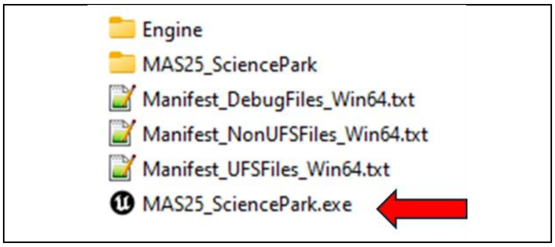
Chapter X
Apparatus Guide

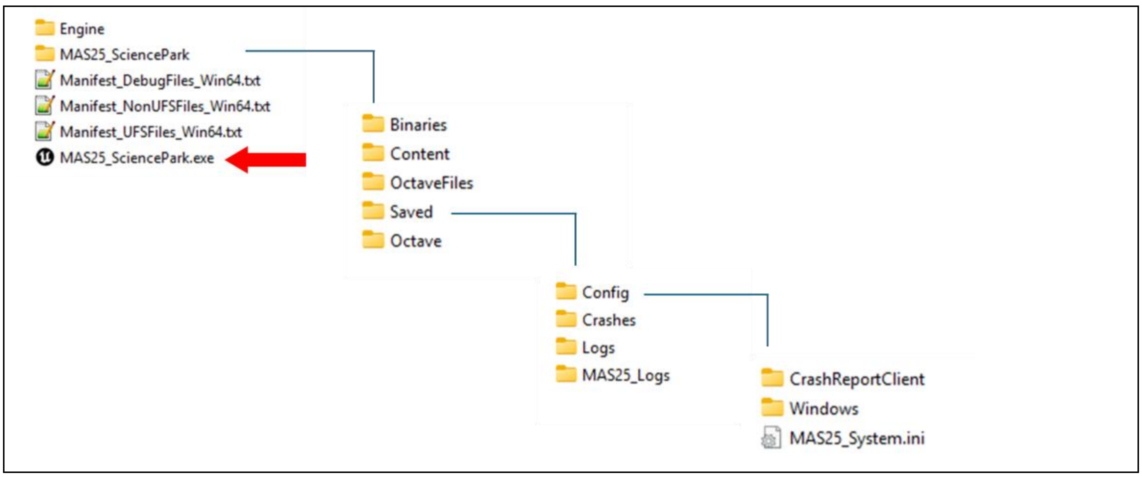
The purpose of this chapter is to give a brief overview of experiments in the current Science Park release and how the user can interact with these as well as starting up the simulation engine.

X.1 Installing and Running

Download and unzip the installation. Open up the root **SciencePark_Release** folder and you will see the following.



To run the engine, double left-click on the .exe file. To interact with the simulated lab, follow the instructions in Section X.2 below. There are some additional folders and files you will need to use. Here's the directory tree structure.



Going down one level there are two important folders: **OctaveFiles** is where Octave script files automatically created by the engine are located. These contain simulation data and can plot this data for you. They are automatically executed when you press **O** in the running level.

The folder **Octave** contains some prepared Octave scripts where you can write in your data, and these will be plotted, usually with associated theory curves.

Within the **Saved** folder there is a **Config** folder which contains the file **MAS25_System.ini**. This is used for advanced configuration of the engine, details at the end of this document.

X.2 A General User Interface

To navigate around the lab, use either the arrow keys or the game keys **W, A, S, D** and the mouse. There are four aspects of the UI: (i) Selecting, starting and stopping an experiment (ii) Setting parameters and initial conditions (ICs), (iii) using the information from the HUD, (iv) working with the auto-generated Octave Files.

X.2.1 Selecting and Running an experiment.

To select an experiment, place the red cross-hair over the experiment and left mouse click. Information about the experiment will then appear on the HUD.	
F1	Start, pause and resume an experiment.
F2	Stop the experiment. You can then change parameters or initial conditions and restart the experiment.
F3	Stop the experiment and reload the default parameters and initial experiment.
X	Stop and leave the current experiment ready to move on to a new experiment. This will write all saved data to disc.
O	Displays Octave generated plots on your screen[1]. Need to hit **X** before hitting **O**.
	To exit the lab press the *tilde* key to the left of the '1'. A black console will open at the bottom of the screen where you should type **quit**. 

[1] Octave must be installed. See section on Configuration

X.2.2 Setting Parameters and Initial Conditions.

The parameters and ICs are different for each experiment and the method of setting is the same for each experiment. Note that current parameters are always displayed on the HUD with specific colour blue.

P	Hit this key to change a parameter, and a menu will appear. Change the parameter you wish, then hit **Done.**
I	Hit this key to change an initial condition, and a menu will appear. Change the parameter you wish, then hit **Done**. Unlike parameters, ICs do not appear on the HUD.

X.2.3 The HUD

This presents information specific to the experiment. But each HUD conforms to identical arrangement. From the top down you will find the following

	Colour
Name of the experiment	Red
Type of numeric solver employed	Green
Current time (real-time)	Red
Experiment parameters	Blue
Values of selected variables (real-time)	Magenta

X.2.4 The Octave Resource

Octave is an open-source software package similar to MATLAB^{R}. All experiments have been designed to log significant real-time data from key variables into an Octave file which also includes commands to generate plots.

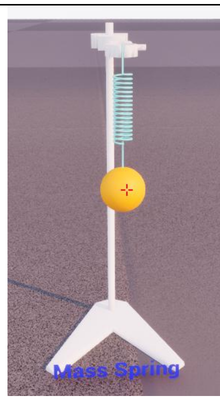
These plots can be generated within the engine, after you have pressed **X** to disengage with an experiment. Plots will appear on your screen when you press **O**.

You may wish to inspect these files. They are located in the folder **Octave_Files** and will have the same name as your experiment.

X.2 A Worked Example

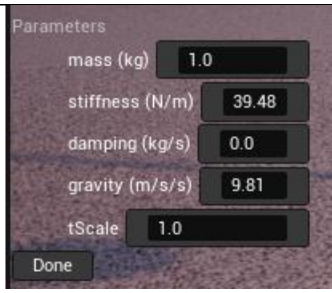
Let’s go through some basic steps needed to run an experiment and gather data. We’ll take the example of the mass on a spring ‘Mass Spring’.

Step1 Select the Apparatus. Navigate through the lab until you find the experiment ‘Mass Spring’ and place the cross-hair on the apparatus, so it looks like this.

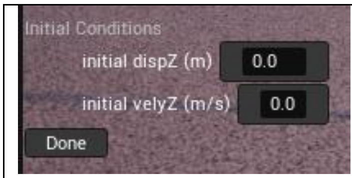


Step 2 Engage the Experiment. Left mouse-click and the following information will appear on the HUD. You have the apparatus name, its default parameters (blue) and variables (magenta) which will be dynamically updated.

Step 3 Check on Parameter and Initial Condition input boxes. Press **P** and the parameter input box will appear. Don’t change anything, but press **Done** to confirm the selection of parameters.



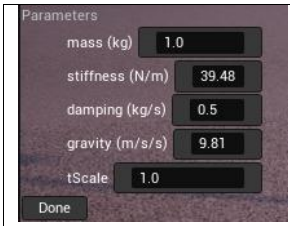
Now press **I** to bring up the initial condition input box. Again, don't change anything, just press **Done**.



Step 4 Start the experiment running. Press **F1** and observe the oscillating mass. Check out the variables being updated on the HUD.

Step 5 Pause the experiment. Press **F2** to pause the experiment. The current variables are maintained.

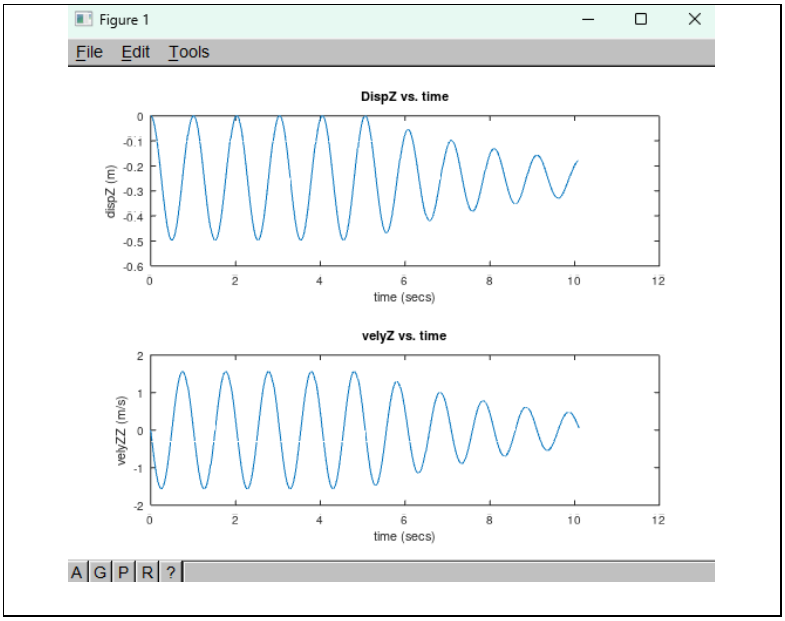
Step 6 Change a parameter. Let's change the amount of damping. Press **P** to bring up the parameter input box, then change damping to 0.5 like this. Press **Done** when you are done.



Step 7 Continue the experiment. Press **F1** to continue using the updated parameters. After a while,

Step 8 Disengage the experiment. Press **X** to disengage the experiment, which makes it stop and saves any collected data

Step 9 Display the plots using Octave. Press **O** and you will get the following plot in a separate window on your screen.

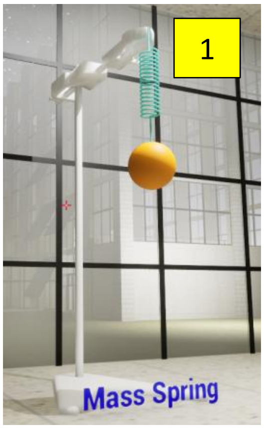


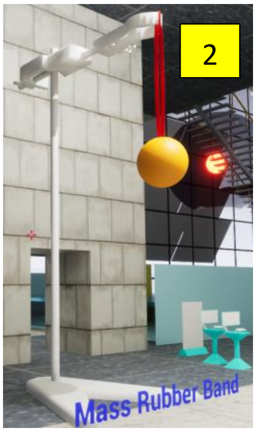
When you have done (perhaps you have taken a screen-snip) then close the black window or click on the window and type any character.

X.2 Ground Floor experiments

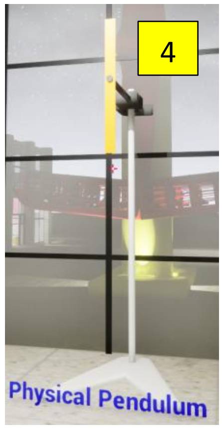
These experiments are intended to explore simple harmonic motion, but there are a few nice extensions and enhancements, such as introducing non-linearity. Also there are some clear engineering applications of the associated physics. Some experiments are located outside the lab building, including several Monster Truck suspension models, and the SkyMaster fairground ride. Here's a short summary of what you can expect; comments are added for experiments which may be unfamiliar.

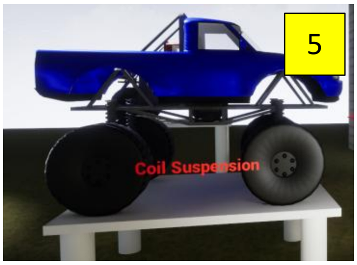
1	Mass Spring	
2	Mass Rubber Band	Nonlinear spring. Compare with (1).
3	Simple Pendulum	
4	Physical Pendulum	
5	Coil Suspension	Linear spring. ¼ suspension model.
6	Air Suspension	Nonlinear spring. ¼ suspension model.
7	Independent Suspension	Full suspension: pitch and roll. Can move passengers around.
8	SkyMaster ride	Fairground ride showing damped driven harmonic motion. Can display period-doubling bifurcation and chaos.
9	Bobbing floater	Simple buoyancy enhanced by added mass, radiation and viscous damping.
10	Gravity Tube	Hypothetical experiment producing periodic non-harmonic motion but open to simple analytical analysis.
11	Rotating M2-3K	Effects of centrifugal force on glider oscillations and equilibrium positions.
12	Hole through the Earth	"journey through the centre of the Earth". Drop Cambridge through this hole and discover it experiences SHM. But what is the period, and does it induce nausea like ship oscillations?

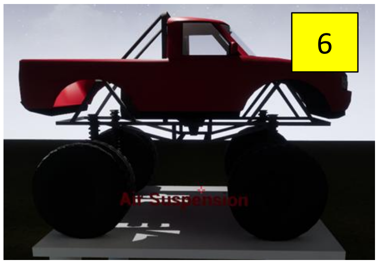

1
Mass Spring


2
Mass Rubber Band


3
Simple Pendulum

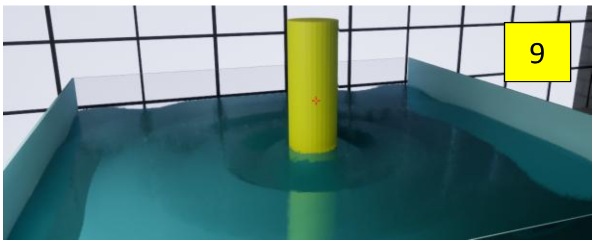

4
Physical Pendulum

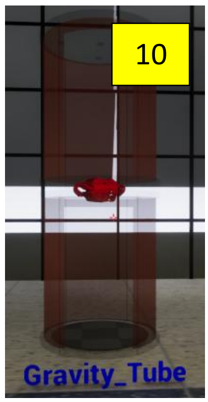

5
Coil Suspension

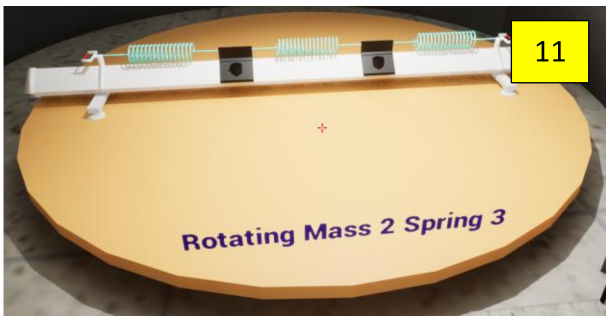

6

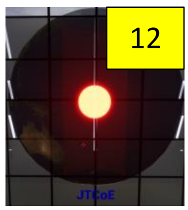

7
Independent Suspension


8
SkyMaster


9


10
Gravity_Tube

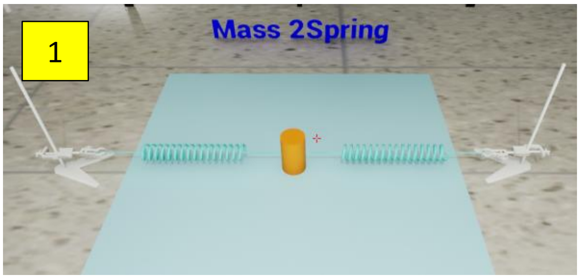

11
Rotating Mass 2 Spring 3

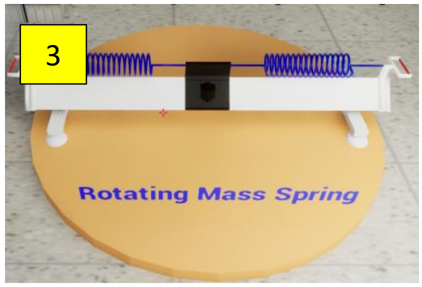

12

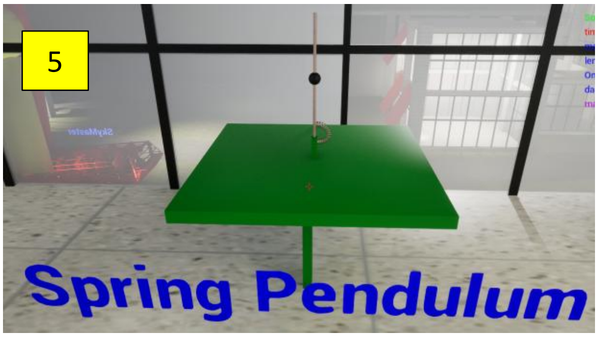
X.3 First Floor experiments

These oscillation experiments are a little more developed. There are several mass-spring (‘MK’) oscillators, and three oscillators are placed on a rotating table, exploring the effects of non-inertial reference frames. All oscillators include some form of non-linearity which can be approximated as a cubic term of displacement. The double-well duffing oscillator is intended to explore the nature of the cubic nonlinearity. The Watt governor provides an engineering application.

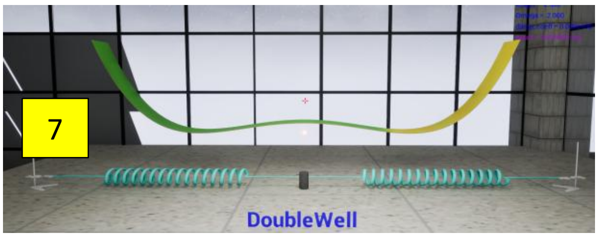
1	Transverse MK-Oscillator	Frequency of small-displacement oscillations.
2	Vertical Loaded MK-Oscillator	Bistable solutions. Energy approach. Effect of loading – unfolding the bifurcation curve.
3	Rotating MK-Oscillator	Effects of rotation. Equal and unequal spring constants.
4	Rotating Pendulum	Oscillations about vertical and also offset due to rotation
5	Spring Pendulum	Analysis as function of stiffness and tilt angle. Solution surface, discussion of bifurcations.
6	Watt Governor	Engineering application
7	Double-Well Duffing Oscillator	Relates oscillations to the potential hill. Compelling visualiation.
8	Simple Air Spring	Expression for stiffness and frequency of small-amplitude oscillations. Effect of non-inertial reference frame.
9	Kapitza Pendulum	Observe fast and slow oscillations. Small and large-amplitude solutions, energy approach.

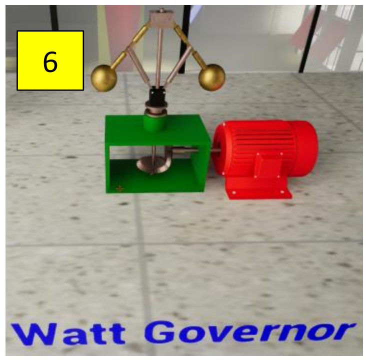

1
Mass 2Spring

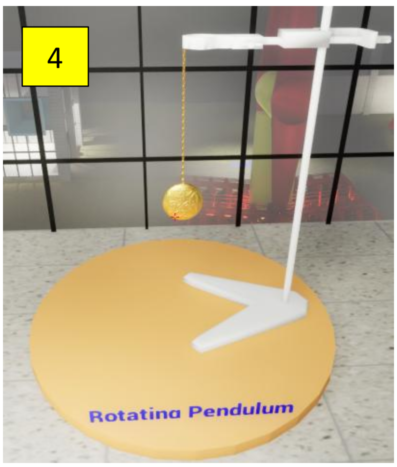

3
Rotating Mass Spring


5
Spring Pendulum


8
Simple Air Spring


7
DoubleWell


6
Watt Governor


4
Rotating Pendulum


2
Mass 2Spring Loaded

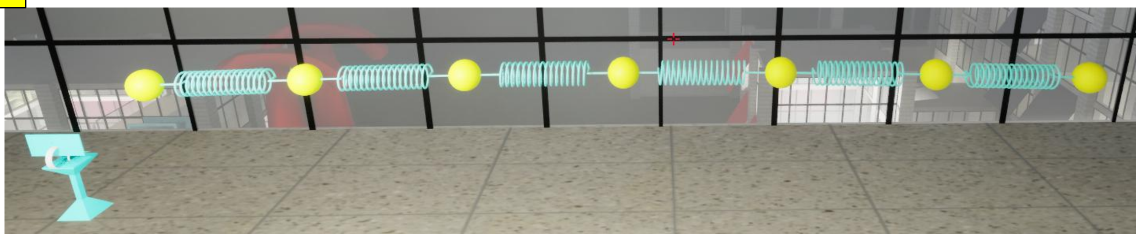

9
Kapitza Pendulum

X.4 Second Floor experiments

This is currently our development, ‘playground’ area where new experiments are being tested, though a couple of these are complete. Here we have the Lumped MK (mass-spring) line which is a step towards developing resources to extend our study of oscillations into waves.

1	Corpower C4 WEC	Commercial wave energy convertor (WEC) exploring how waves interact with an excited buoy.
2	Lumped MK Line	Experimental chain of masses connected with springs. User can choose number of masses. Demonstrates normal modes and pulse propagation. To be developed.

1



2

X.5 Configuration Files

When the engine is started, each experiment is provided with *default parameters* which we have defined. However, the instructor can change these, so that their preferred parameters become the *default*. This is done by editing the text file **MAS25_System.ini** file using any text editor (we recommend Notepad++). The file is found as indicated in the directory tree.

X.5.1 Parameters for each Experiment

Let's look at a particular section in this file for the experiment "Rotating_Pendulum".

```
[/Script/MAS25_SciencePark.MAS25_Rotating_Pendulum]
scaling = 100;
actorName = "Rotating_Pendulum"
defaultSolver = "RUNGE_KUTTA_FEHLBERG"
logInterval = 0.01
mass = 0.5
length = 2.5
Omega = 2.0
damp_coeff = 0.0
offset = 0.0
bIncludeFFT = false
```

Here's a line-by-line digest

Line 1	Defines the scaling between physical length (m) and Unreal Units. Don't change
Line 2	Name of the actor. No need to change
Line 3	Numeric Solver. Under development, so leave alone
Line 4	Time interval (s) when data is logged. Could be reduced to 0.1 if you find your data files are too large
Lines 5-9	Parameters relevant to this experiment. Here you can select your preferred *default* parameters.
Line 10	For this experiment, the ability to calculate the frequency spectrum is included. This is currently off. You could experiment with this.

X.5.2 Parameters for the Engine

These parameters help configure the Engine, and they trickle down to each experiment.

X.5.2.1 Octave Installation

```
[/Script/MAS25_SciencePark.MAS25_Actor]
defaultSolver = "RUNGE_KUTTA_FEHLBERG"
editorOverride=true
bOctaveInstalled = true
OctavePath = "C:\\Octave\\Octave-5.2.0\\mingw64\\bin\\octave-cli.exe"
enableTick = false
; above set true for the waveBody research stuff
```

There are to lines which are important here which refer to the installation of Octave on your computer. We strongly recommend you install Octave, and we hope you find this a useful tool in working with data, exploring functions, finding roots, solving ODEs and all sorts of stuff we would like our students to become familiar with. Please follow this link https://octave.org/download .

If you have not installed Octave (grr), then you must set **bOctaveInstalled = false**.

When you have installed Octave, then you must set **bOctaveInstalled = true**. Also you must provide the path to your Octave installation. The above shows a typical example. Please note the double backslashes.

X.5.2.2 Player Movement Speed

When moving through the lab, you will experience a baseline speed, and an accelerated speed (by pressing **Shift**). Some users will want to move slowly, others fast. These speeds are set in the following configuration group, please feel free to tweak these.

```
[/Script/MAS25_SciencePark.MAS25_PawnX]
slowSpeed = 0.45
fastSpeed = 1.5
```

X.5.2.3 HUD Font Scale

We have chosen a particular font size for the HUD which suits our development platform. You may find this too small. You can change this by editing the value of **fontScale** in the configuration group

```
[/Script/MAS25_SciencePark.MAS25_HUD]
fontScale = 1.5
```