

# Worksheet 1

## Monster Truck

### 1.1 Initialization

Download and unzip the project **WindowsNoEditor** then run the file **MAS22\_SciencePark.exe** on a PC. You will find yourself in the Immersive Environment. The Monster Truck is a forced harmonic oscillator; the following activities will introduce you to forced oscillators, in preparation for Vibration Energy Harvesters (VEHs). The workflow using the science park is detailed in a separate document.

### 1.2 The Monster Truck

Search for the monster truck, it's outside somewhere and shown in the graphic on the right. There are two bits of theory you need to know. First the *natural frequency of vibration* of the truck when it is not forced and when there is zero damping is,

$$f = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

where  $k$  is the spring stiffness and  $m$  is the mass of the body. You can get these when you run the simulation.

The second bit of theory is the amplitude response curve which tells you the amplitude (in m) of the body's motion as the driving frequency is changed. You should keep an eye on this as you are doing your investigations. this curve is shown below.

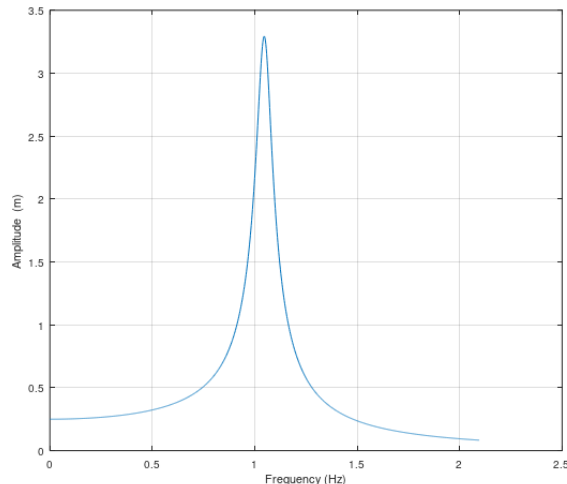
(a) Now download and unzip **Octave\_Release**. Open up Octave and point it to where you have unzipped the Release. Use Octave as a calculator to calculate the natural frequency from the expression given above. Look at the peak of the

<b>Purpose</b>	To understand current research and applications of Vibration Energy Harvesters.
<b>Files Required</b>	Zipped Unreal Engine level and Octave Scripts
<b>ILO Contribution</b>	Position Paper 1 (part 2) Learning Outcome 2.
<b>Send to Me</b>	
<b>Homework</b>	Read Chapter 19

### Chapter 19.3



frequency response curve and find the approximate frequency of this peak. What do you notice?



### 1.3 First Investigations

Here we shall perform some introductory investigations to get to know the model.

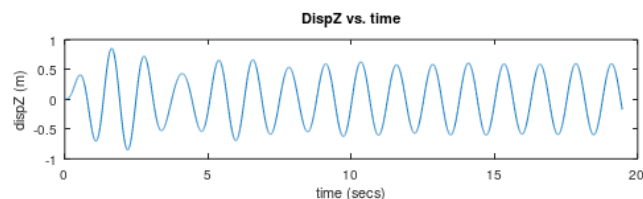
```

Monster_Truck
Solver: Runge-Kutta-Fehlberg
time = 0.000000
mass = 600.000000
damping = 0.500000
stiffness = 26000.000000
forcing amplitude = 0.250000
forcing frequency = 0.800000
maxDispZ = 0.000000
maxVelyZ = 0.000000
  
```

(a) Now cross-hair left-click the truck and check the parameters on the HUD match those shown on the left.

(b) Press F1 to start the simulation and observe the movement of the driving plate and the truck body. You should find they are not the same at first, but after a while they occur together – with the same frequency. Hit key **X**.

(c) Navigate to the folder **OctaveFiles** and open the file **Monster\_Truck.m** in Octave. It will draw some plots. Look at the plot of **dispZ** versus time. It should look something like this,



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You can see that at first the oscillations are irregular, only after around 10 seconds or so do they become regular with a constant amplitude. The irregular part is called a *transient* and you must avoid this when making measurements.

(d) Now cross-hair select the truck again and press F1. Keep an eye on the value of **maxDispZ** and run the simulation until this is fairly constant (say to 3 decimal places). At this point the *transient* is gone. Note the value of **maxDispZ** and **forcing frequency** and check this point lies on the frequency response plot (above).

### 1.4 Constructing a Resonance Curve

Here we are going to collect data, how the amplitude of vibrations changes with forcing frequency.

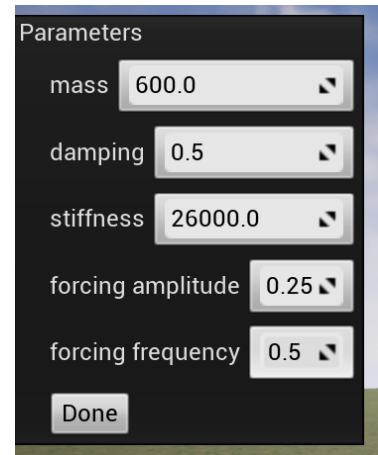
(a) Make sure the truck is selected but not running. Now press **P** to bring up the parameter menu. Change **forcing frequency** to 0.5 so the dialog box looks like the one on the right, then press **Done**. Check the value in the HUD has been correctly updated.

(b) Run the simulation keeping an eye on **maxDispZ** and when the transient is passed, press **F1** to halt the run and note down the value of **maxDispZ**.

(c) Repeat the above building up a table like this one. I have chosen some forcing frequencies; you could try more.

forcing frequency	maxDispZ
0.5	
0.8	
1.0	
1.25	
1.5	

(d) Open up the Octave file **Monster\_Frequ\_Resonance.m** and insert your data as explained in the file. You will need to uncomment-out a line (green) at the bottom of the script.



Run the file and your data should appear (and agree with) the above plot. The script will ask you for the value of **damping** which you can get from the HUD display.

### 1.5 The effects of Damping

Here we shall increase damping to 2.0 and note the effect on the amplitude response.

(a) Repeat the above data-collection, after setting **damping** to **2.0** in the parameter dialog.

(b) Enter your data into the Octave script (the second data set) and plot this out, you will need to set the new value of damping when prompted.

(c) If you want both data sets plotted, then run it with damping set to 0.5, then at command line type **hold on** then run again with damping set to 2.0

### 1.6 Takeaway

Here are the important points which you should have found, so make sure you appreciate these. These points are very important when we come to studying actual VEHs.

(a) The amplitude of response is large for *a small range of frequencies*. So any practical device need to be *tuned* to the frequency of the vibration source.

(b) The range of frequencies which gives a significant response can be increased by *adding more damping*. But this reduces the size of the response.

(c) Therefore, choosing the value of damping implies a *trade-off* between frequency range which is accepted, and size of response.

(d) Vibrating systems show an initial *transient* where their response is not steady. There is not much to do about this

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(though damping may reduce the transient time), so this is relatively unimportant in designing practical VEHs.