

# Worksheet 3

## Piezoelectric VEH

**Chapter 19.6**

### 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.

### 1.2 The Piezoelectric Harvester

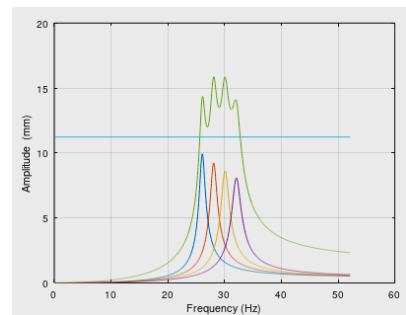
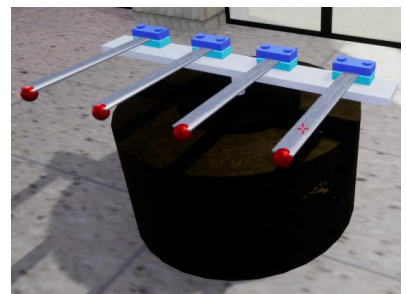
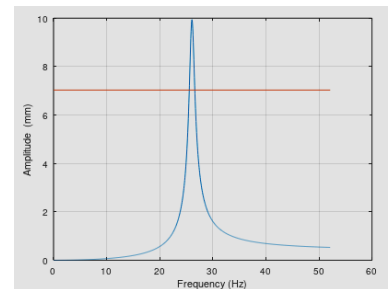
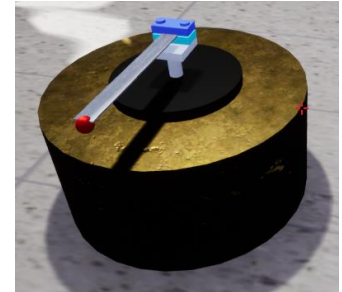
Two Piezoelectric Harvesters PIEs are provided in the level, shown on the right. The first is a single piezoelectric beam with a mass on the end; the size of this device is quite small, a few 10's of mm in length, you can get the mass and stiffness from the simulation. The mathematical model is very similar to the Monster Truck, so we expect a similar amplitude response (also on the right) where there is a small useful bandwidth.

To make the PIE more useful in harvesting over a larger frequency range, four devices are combined, each device responds to a slightly higher frequency; you can see the individual response of each element, and the combined response in the diagram on the right.

You can see that the frequencies are several 10's of Hz (cycles per second). To help observe the vibration, time has been stretched (slowed down) in the simulation.

### 1.3 The Single PIE Response curve.

(a) Vary the forcing frequency (here called the **driveFreque**) and collect values of **maxDispZ**. You might be able to get these from the HUD, but for higher frequencies you might need to consult the Octave file **VEH\_PIE.m**



(b) Plot your results by adding your data points to the file **PIE\_Frequency\_Response\_New.m** in the Octave downloads.

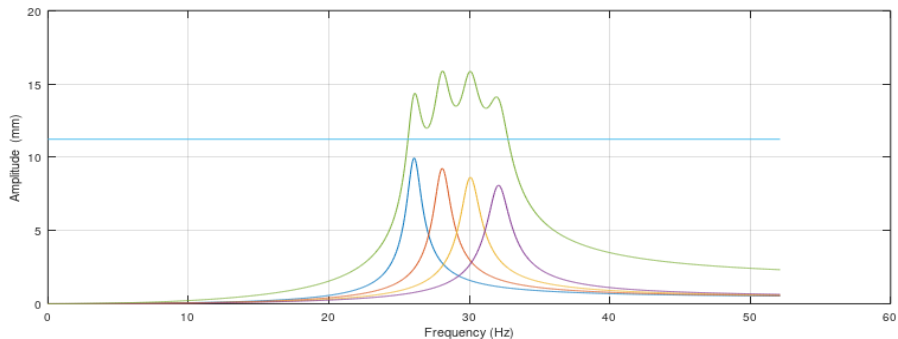
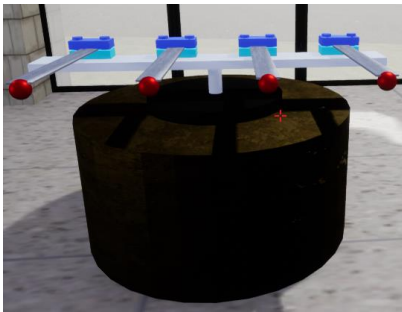
(c) Measure the half-power bandwidth (HPBW) and calculate the 'Harvesting Quality' factor. If  $f_U$  is the upper frequency of the HPBW and  $f_L$  is the lower frequency, then the Quality factor is calculated as

$$Q_H = \frac{(f_U - f_L)}{0.5(f_U + f_L)}$$

You may wish to compare this with the quality of the Monster Truck and Maglev VEH.

## 1.4 Observing the Multi-PIE

(a) Navigate so you are in front of the device as shown below. The frequency response curve is also reproduced.



Use the above curve to choose a range of **driveFrequ** so that each of the multi-PIE elements is excited in turn. Start with the left and work your way towards the right.

(b) Choose a **driveFrequ** so the two middle elements are excited.

(c) Confirm that the device does not respond when the frequency is too low or too high.

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### 1.5 Multi-PIE Response

(a) Vary the frequency over a suitable range, and note down the values of **avPower** either from the HUD or from the Octave file.

(b) Enter your data into the Octave file **Plotit.m** and plot your data. Don't expect a simple curve, since you have a complex system of four elements vibrating!.

(c) Estimate the HPBW (the horizontal line is drawn at half the peak power).

(d) Calculate the Harvesting Quality Factor and compare this with the single PIE device. What do you conclude?

### 1.6 Takeaway

You should understand that the PIE harvester behaves like the Monster Truck and has a small HPBW.

A good way to improve the harvesting Quality is to use several PIE elements in parallel, each tuned to a different frequency.

How do you suppose each element is tuned to a different frequency? There are several ways to do this.

Is there a downside with constructing a multi-element device?