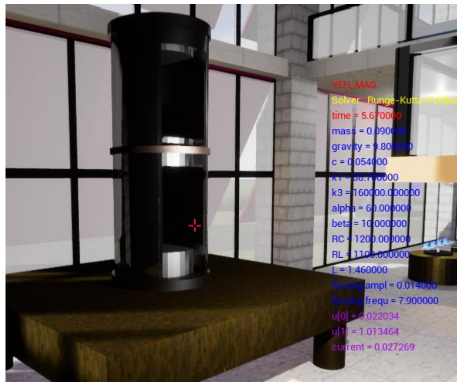
Worksheet 2
Maglev VEH

Chapter 19.5

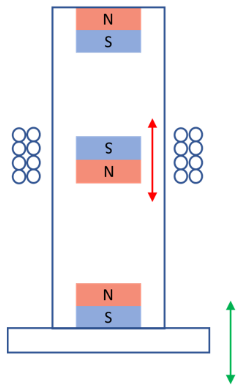
1.1 Initialization

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 Maglev

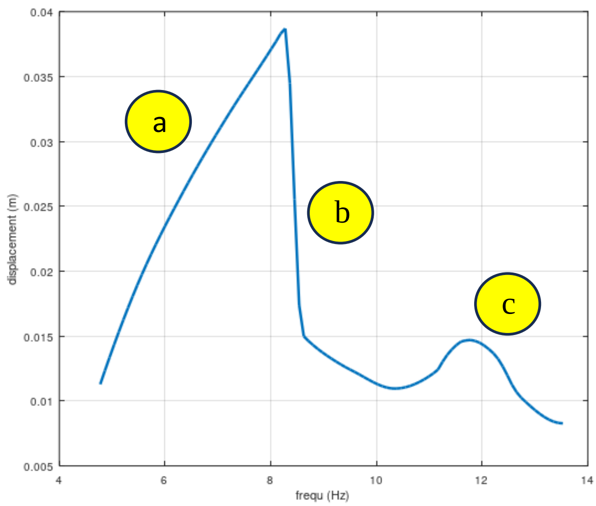
Search for the Maglev, it's inside the VEH lab on the ground floor. Make sure you position yourself so you can see the opening in the front as shown in the box on the right. The internal structure of the Maglev is shown in the second box. Thre three magnets conspire to levitate the central one, so it can move with very little friction. The green arrow shows the excitation platform moving (like the Monster Truck), the body and magnets move, but the middle magnet lags behind. The circles show a coil of wire fixed to the body. This means there is relative motion between middle magnet and coil which by Faraday's law of induction tells us that there is a voltage (or current) induced in the coil. That's the source of power.

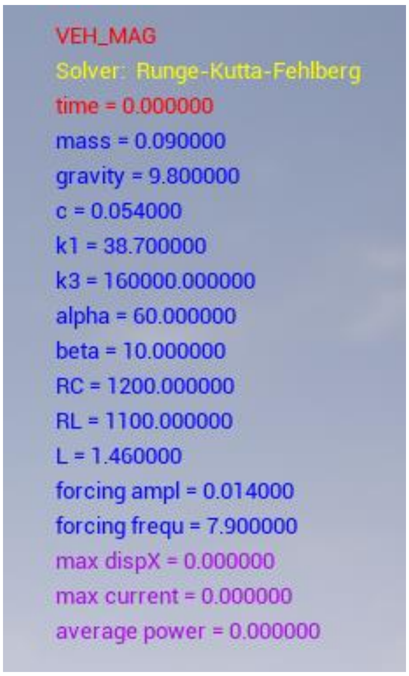


What is the difference between the Monster Truck and the Maglev forces? Well, the Monster Truck has coil suspension where force is proportional to spring displacement, but the forces between the magnets is not proportional, but it increases with middle magnet displacement. This is easy to understand, forces between magnets increase when they are closer together.

Like the Monster Truck, we need to look at the amplitude frequency response plot, shown below. It is worth looking back at the Monster Truck equivalent, since they are so different.

First the ‘resonant peak’ (around label **a**) seems much broader, so the Maglev should extract energy over a larger range of frequencies. Second, there is an abrupt jump down at **b**, this is due to the nonlinearity of the magnetic force. Third there is a second hump at **c** again due to the nonlinearity. We shall investigate all of these in turn.





1.3 The Frequency Response curve.

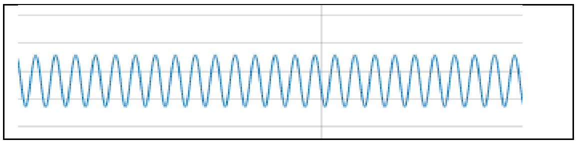
(a) First check on the current parameters. Find the Maglev and select it to bring up the parameters which should be as shown on the left. If anything is different, press **P** and fix it.

(b) Let’s first investigate data in region a above. Collect data as you did for the Monster Truck. Vary the **forcing frequ** and note down the **max dispX** (which should be dispZ, grrr). I suggest you choose frequencies in a range of 5 – 9Hz, perhaps 10 data points. *Remember to keep an eye on the varying **max disp** on the HUD so you only take readings when the transient is passed.*

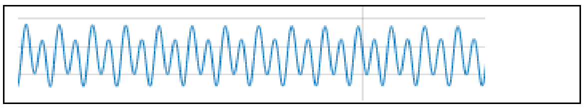
(c) Open up the Octave file **Maglev_Frequ_Response.m** and add your data points where indicated. Check that you have discovered the *jump phenomenon*.

(d) Now let's look for period doubling. Choose two frequencies, one to the left of the hump **c** and one near the centre of the hump. Run the Maglev using **P** to set the first frequency, and wait till the transient is passed. Now use **P** to set the second frequency and tun for some time, say 40 secs (it's not possible to look for a transient since things are changing).

Now navigate to the **OctaveFiles** folder and run **VEH_MAG.m** which will give you the **dispZ** response. Make sure you see non-period-doubling which looks like this,



and period-doubling which looks like this,



1.4 An Investigation into Power Produced

(a) Run the Maglev over a range of frequencies, say from 5 – 9 around the jump, then before and after the period-doubling hump. It's hard to get the data from the HUD, better to look at the Octave plot and extract the values there.

(b) Create your own Octave script (or use **Plotit.**m provided) and plot these values. Make a note of the largest power you found; it will be useful to keep this as a reference value.

1.5 The effect of the Power Take-off

There are two important resistances in this device, **RC** is the resistance of the coil producing the voltage and **RL** is the load resistance. The coil resistance is fixed by the length of the wire used to make the coil; we cannot change this. But **RL** is the *load* resistance, i.e., the resistance of the *power take-off* device. We do have control over the size of **RL.**

Theory tells us that for maximum power take-off we should choose **RL** to equal **RC** but this theory was developed for *linear* systems and our Maglev is non-linear, so this theory may not apply exactly.

(a) Run the simulation, set the **forcing frequency** to something lower than the jump frequency. Now for various values of **RL** read off from the HUD the **max current.** I suggest resistances in the range 500 – 4000 Ohms.

(b) You can calculate the peak power for each resistance value like this

$$\textbf{power} = \textbf{current}^2 * \textbf{RL}$$

Calculate your powers and use Octave to plot a graph. Is there a value of **RL** where the power is a maximum?

1.6 Takeaway

Here are some points which you should have discovered and understood.

(a) The amplitude response curve looks broader than for the Monster Truck with a high amplitudes for a larger range of vibration frequencies.

(b) Nonlinearity has introduced a new *jimp phenomenon* and also a *period doubling* region. Perhaps there are additional effects we have not observed. So we should be careful when using nonlinear systems in reality.

(c) There is an optimum value of power take-off resistance though this may not agree with the predictions of linear theory.