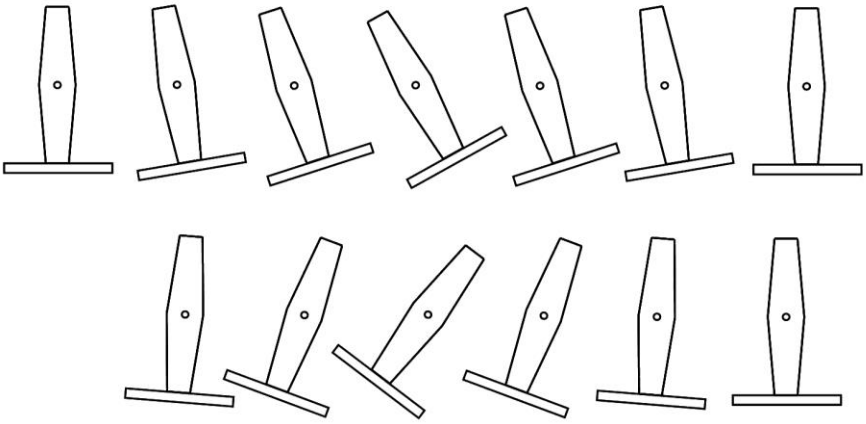
SkyMaster Investigation Guidance

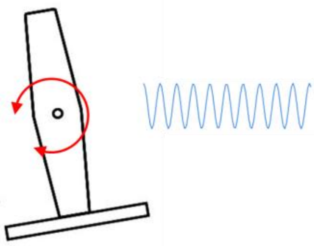
1 Background

The SkyMaster is a fairground ride located at Butlins in Minehead, you can see its structure in the picture below. There are two cars on the ends of arms, they rotate in opposite directions. The operator applies driving force to the cars to increases their amplitude of oscillation and eventually they pass over the top where the riders are upside down. So, we are looking at an *oscillating* system, but one which can 'go over the top'. This is quite unusual.

Here's a diagram showing the SkyMaster oscillating with a small amplitude. The mathematical model (which we will not go into this time) tells us that the behaviour of these small amplitude oscillations is straightforward and is like a pendulum clock or a car suspension. When the oscillation amplitude is large (say above 90 degrees) then the behaviour is much more complex, and therefore interesting to investigate.



On the real ride, the operator has a joystick which he manipulates to add rotational force ('torque') to the centre of the arms from electric motors. In our model we shall use a periodic function (sine wave) since this removes the human out of the loop and makes investigations more controllable. Here's the idea.

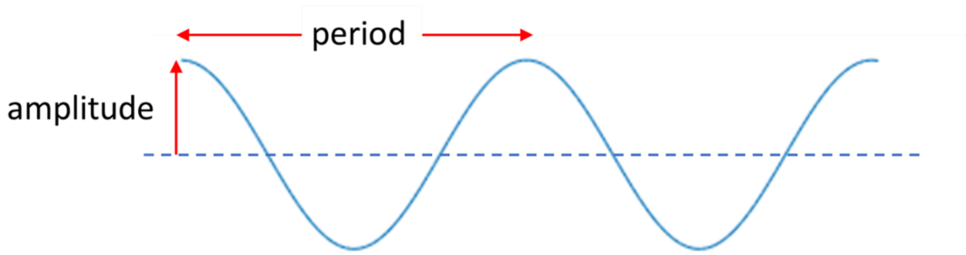


You can see the sine wave torque applied to the motor (blue curve) to force it first clockwise then anti-clockwise.

2. Some Theory (no maths!)

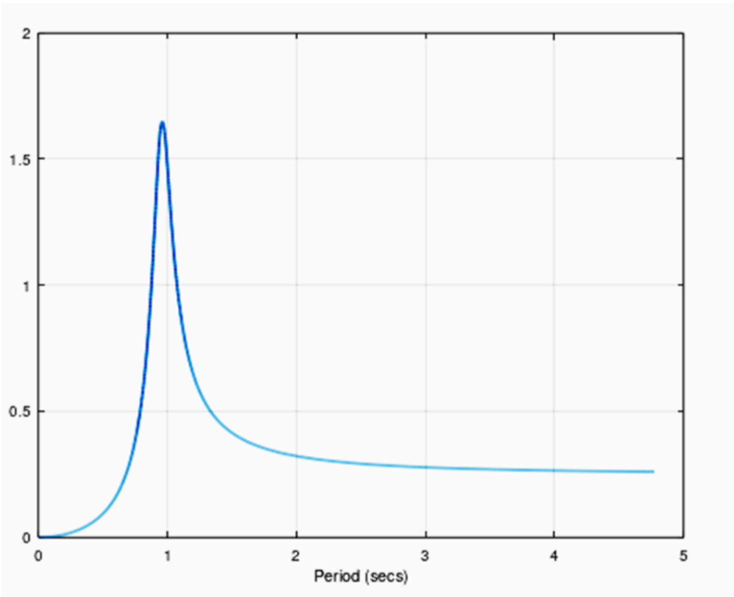
2.1 Some Definitions

Definitions of *period* (measured in seconds) and *amplitude* (measured in degrees or radians) are shown below. Basically, the period is the time taken for one complete swing from a starting angle, over to the other side and back to the starting angle. The amplitude is the maximum angle swung to.



2.2 Response to Periodic Forcing

For small angles, the amplitude of the SkyMaster swing has a predictable relationship with the forcing period. This is shown in the response curve below. You can see as the period is increased from low to high values, in successive experiments, then the amplitude rises up to a peak, where we say the SkyMaster 'resonates' with the applied drive, then it falls again. The vertical axis is in radians. To get degrees, multiply by 180 and divide by *pi*.



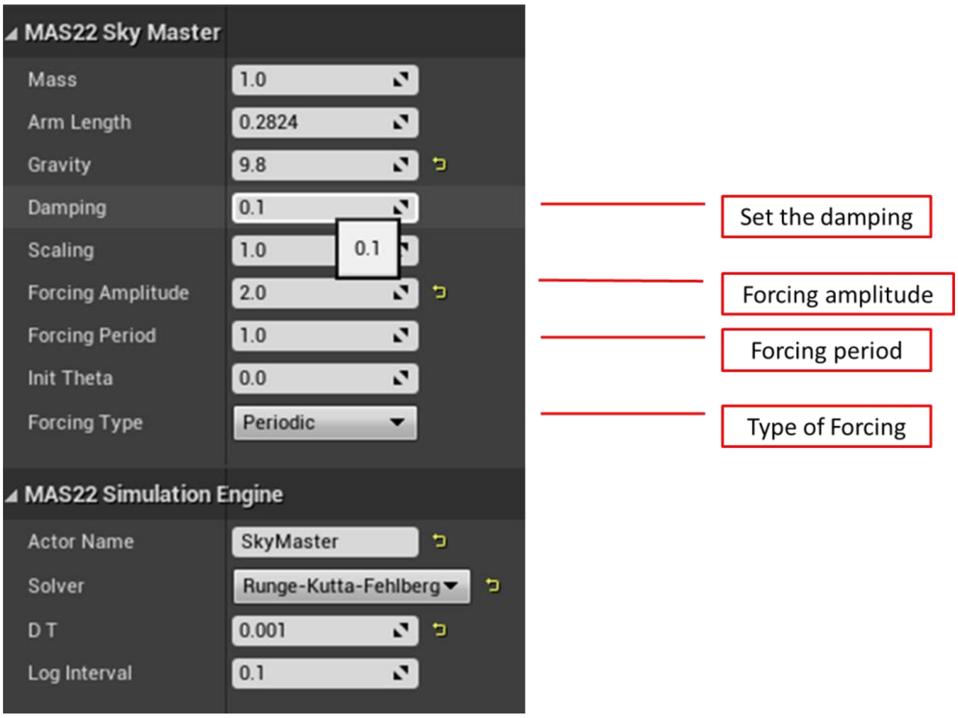
For larger amplitude swings, your data will not lie on the above curve; that will be the subject of your investigation.

3. Model Parameters and Unreal UI

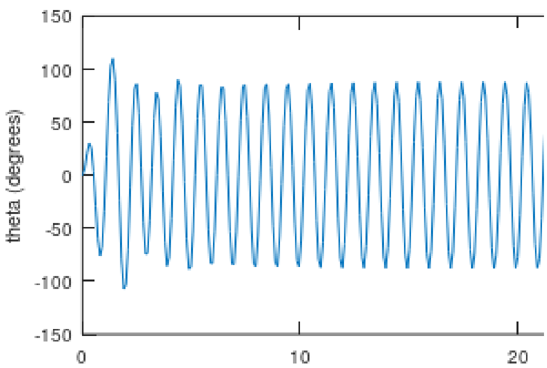
Here are the principal model parameters and notes on which may be used in investigations. The actual values are not physical but have been chosen so you will have interesting results delivered on a short time scale.

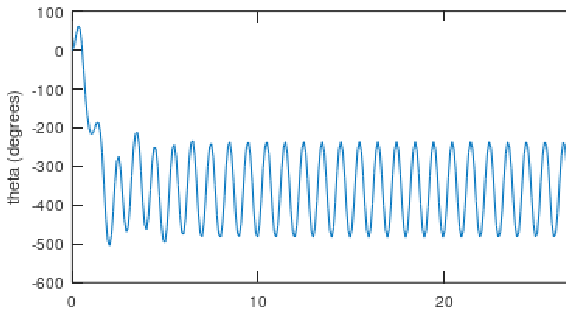
mass of car	Dominated by the structure, depends a little on passengers
length of arm	Fixed by the structure
gravity	Fixed
damping	Can be changed
forcing amplitude	Key parameter which can be changed
forcing period	Key parameter which can be changed

Here's the Unreal UI which shows the default parameters



The engine will write an Octave plot file in the folder **OctaveFiles**.. Just type the Actor Name (see above) on the command line and you will get some plots. Let's have a look at a couple you may find. The left shows an initial 'transient' where the SkyMaster settles into a steady oscillation. The one on the right shows the SkyMaster going over the top, performing one complete rotation before settling into a steady oscillation around its total rotation of 360 degrees





4. Suggested Investigations

4.1 Investigating low-amplitude oscillations

Change the **Forcing Amplitude** to 0.05 and vary the **Forcing Period** in a range between, say 0 and 2.0. Collect at least 5 data points. Add them to the script **SkyMaster_Resonance_Curve.m** (in the data array) which will plot them on the above curve. Make sure you input 0.05 as forcing amplitude to the Octave script. You will find there is a very good agreement.

4.2 Large amplitude oscillations.

Change the **Forcing Amplitude** to 1.0 and vary the **Forcing Period** in a range between, say 0 and 2.0. Collect at least 5 data points. Add them to the script **SkyMaster_Resonance_Curve.m** (in the data array) which will plot them on the above curve. You will find there is not a good fit.

4.3 Major study of effect of Forcing Amplitude

Here you will keep the Forcing Period fixed (**= 1.0**) and change the **Forcing Amplitude**. The SkyMaster will show a wide range of behaviours including going over the top. You should record the Octave plots of theta against time for your paper.

This is a **major study**: you will need to run each simulation for around 300 seconds of simulation time. You will also need to test a large number of parameter values. This is an ideal opportunity for **planned teamwork** where you share the investigative load, and of course share results.

I suggest you investigate values of forcing amplitude initially in the range 0.5 to 5.0. Very interesting things happen close to 5.0. Then take a close look at values in the range 5.0 to 5.5, you will find some weird stuff here. You may want to divide both intervals into 10 separate investigations, hence **planned teamwork**.

As I mentioned, you will find a *huge* range of patterns (of theta against time). You should aim to ***classify*** these patterns into similar groups, A, B, C, D, … and see how these groups are organized along an axis of increasing forcing amplitude.

4.4 Investigations into Non-linear behaviour

Here you will drive the SkyMaster into its non-linear region of operation. The 'slow' parameter set for this is

mass	1.0
armlength	5.0
damping	1.0
forcing Amplitude	3.0

You should vary the **Forcing Period**. I suggest you look (initially) at the range 4.0 – 6.0 then perhaps extend this. Collect say 10 data points. Put your results into the script **SM_Slow_ResTest.m** which will plot them on a 'bent' resonance curve.

Further investigations and information about underlying theory will be available if you ask.