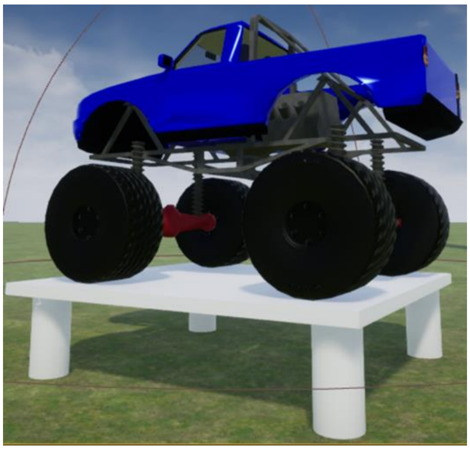
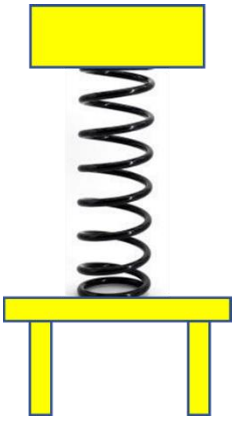
Monster Truck Investigation Guidance

1 Background

Here we'll be investigating Monster Truck suspension. Almost, I have set up the model for a Land Rover since I drive one. Here's the two suspensions we'll be investigating. On the left there is the coil suspension, and, on the right, there is the air suspension. These are *springs*. Also, in the centre of the spring you can see the *shock absorber* which provides *damping* to reduce oscillations of the Land Rover body. Air suspension has this built into the air circuit.

The scenario we shall be using is an MOT test rig to check the damping of the shock absorbing system. We don't have that in the UK, but it is widespread on the Continent. Here's the arrangement in Unreal, and a graphical representation.

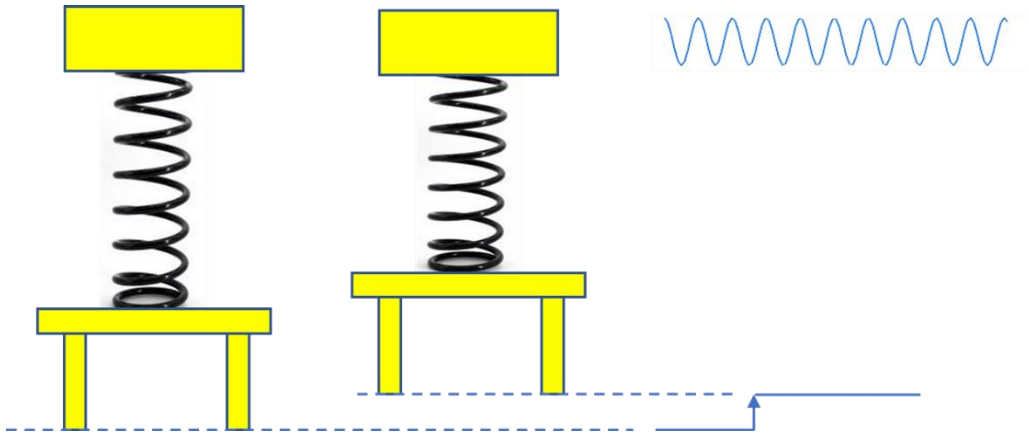




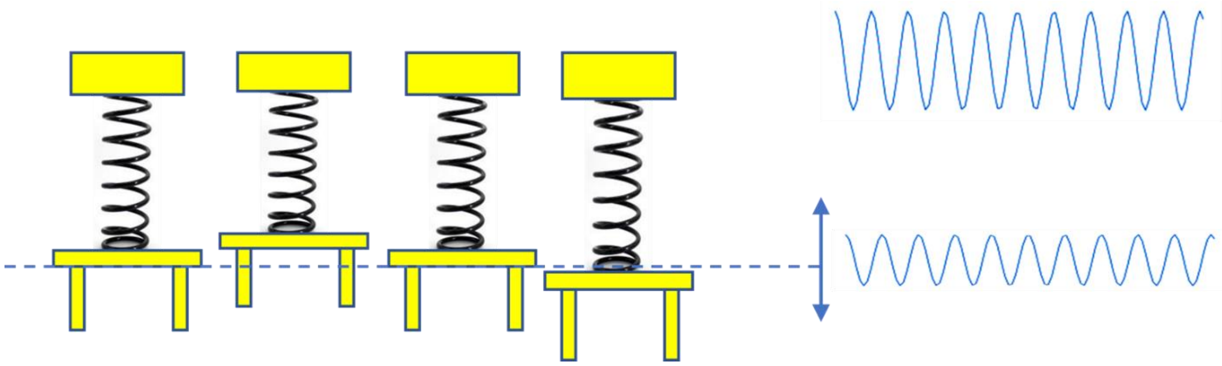
How this works is that everything starts at rest. Then the floorplate moves, and we monitor how the Land Rover body moves with time. In fact, it *oscillates*.

There are two approaches to driving the floorplate. Either we can apply a sudden change in vertical displacement, so the Land Rover has run over a curb. Or we can apply a periodic displacement (perhaps a sine wave) which represents travelling over regularly-spaced cobbled roads (known as 'Belgian pave').

The situation for the sudden change looks like this. From left to right the floorplate moves up a jolt. The Land Rover body responds by oscillating! So we could do a series of investigations around this situation.



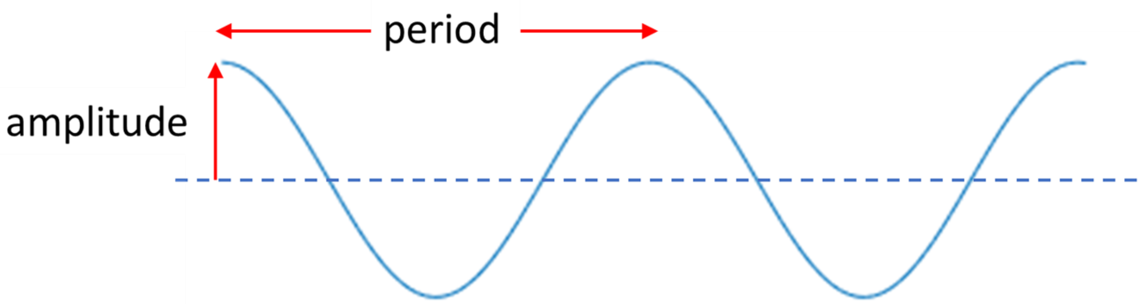
The situation for a periodic excitation is shown below. The floorplate moves up and down with a particular *amplitude* and a particular *period* (we'll check out those definitions later). The actual amplitude of the Land Rover body depends on a shed-load of parameters, we shall investigate some of these. In the diagram below the body moves with a larger amplitude than the floorplate excitation. This is reasonable since the floorplate is pumping energy into the system



2 Some Theory (No maths)

2.1 Some Definitions

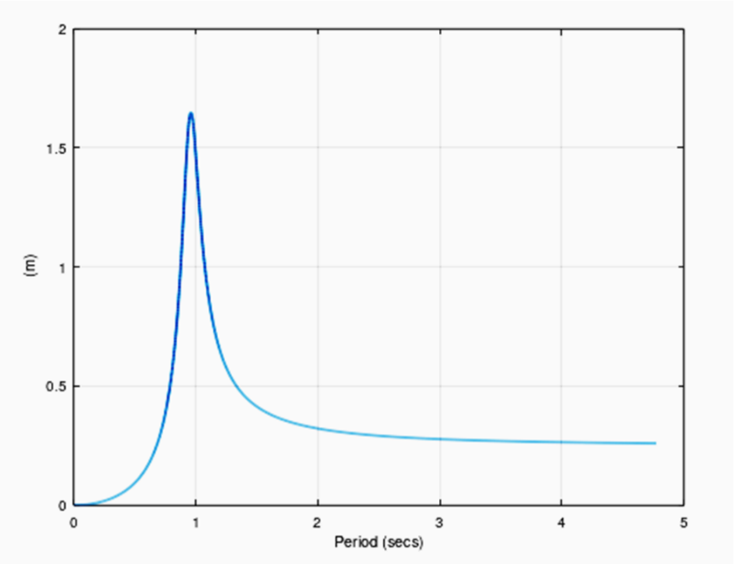
Definitions of *period* (measured in seconds) and *amplitude* (measured in metres) are shown below. Basically, the period of an oscillation is the time, in seconds, it takes to return to an original value. Typically, we shall measure the displacement of the Land Rover body. The amplitude is the vertical distance the body moves upwards, from the static displacement (people in the Land Rover) but there is no bump or excitation.



2.2 Response to Periodic forcing

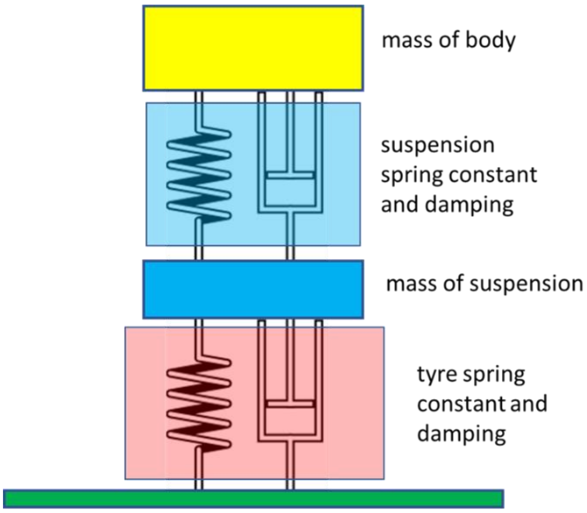
This graph shows how the amplitude of the oscillations depends on the period of the floorplate displacement. A zero value of period means there is no excitation, so the body does not move. As you run a series of experiments increasing the forcing period then the amplitude first increases an hits a peak, this is called *resonance*. Then the amplitude falls again and approaches a constant value.

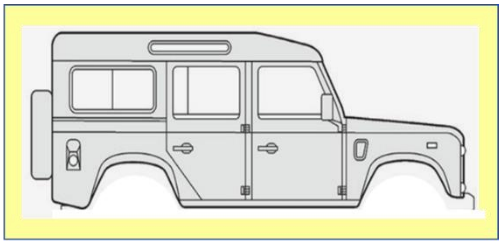
Nota Bene This only applies to the **coil** spring. **Air** suspension is much more interesting

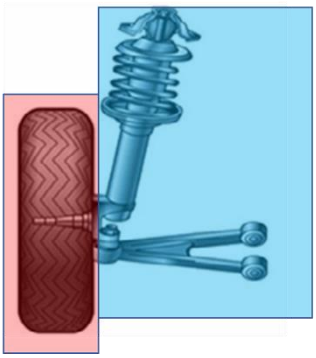


2.3 The Coil Suspension Model

If you were studying on a MechEng degree course, at this point you would be presented with the mathematical model known as the "quarter car" model. This just means looking at one of the four elements of suspension in a 4-wheeled car. The diagram below shows the model (without the maths). Don't worry, we shall not be using this model, rather a simplified one, but it's good to know about current wisdom.

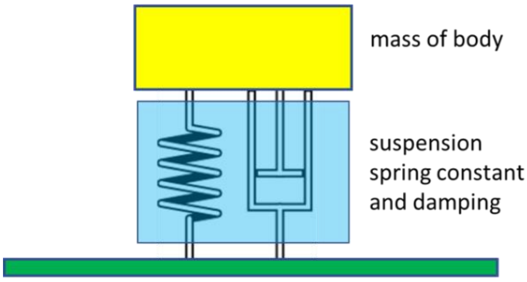


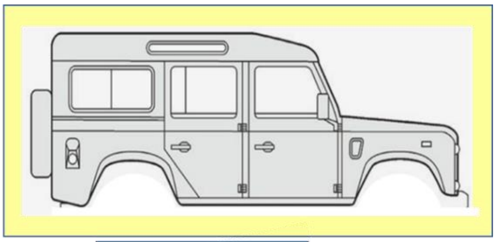


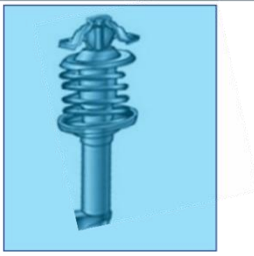


On the left you can see a diagram which represents the *conceptual* model of the suspension system, and on the right, you can see the associated physical components. I have attempted some colour coding to show the correspondence. So, at the top we have the Land Rover body (yellow). This sits on the suspension spring and damping (light blue) and the suspension has mass (blue block). Finally, the suspension is connected to the types which have stiffness and damping (light red).

In our simplified model, we shall forget about the tyres and the mass of the suspension. So, we connect the Land Rover mass, through the suspension spring and damping directly to the road (green). Here we have it,

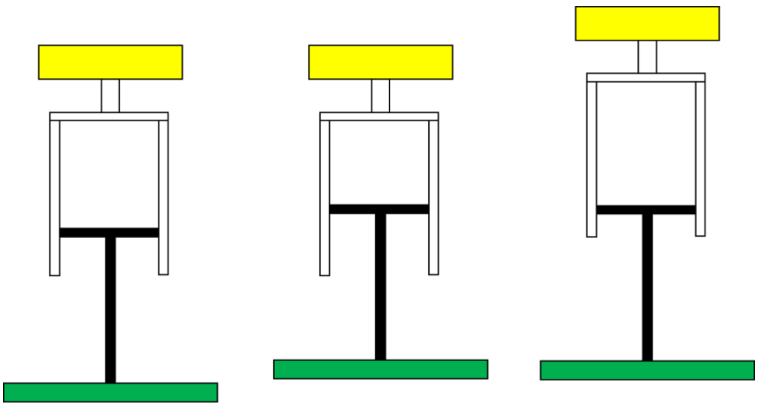






2.4 The Air-Spring Model.

Let's have a *conceptual* look at the air-spring model, in the diagram below; on the left you see the yellow Land Rover body and the green ground. Attached to the body is the outer suspension case (unshaded rectangles) and the piston (shaded) which contains the air in the cylinder. On the left we have the static equilibrium case where the suspension is supporting the dead weight of the vehicle. The centre image shows the ground rising (the Land Rover has hit a bump), and the piston rises. So, the volume of gas in the cylinder is now at a higher pressure (since it is compressed) and this forces the Land Rover body upwards (right image)



Of course, as the piston rises the gas volume becomes smaller and its pressure increases, so there must be a mechanism to release the gas if the pressure becomes too large. Also, there is a maximum displacement. For the Land Rover spring, my theory puts this at 0.5m which is built into the MAS22 simulation, (the JLR documentation says it's around 0.3). These facts are not built into the simulation.

3. Model Parameters and Unreal UI

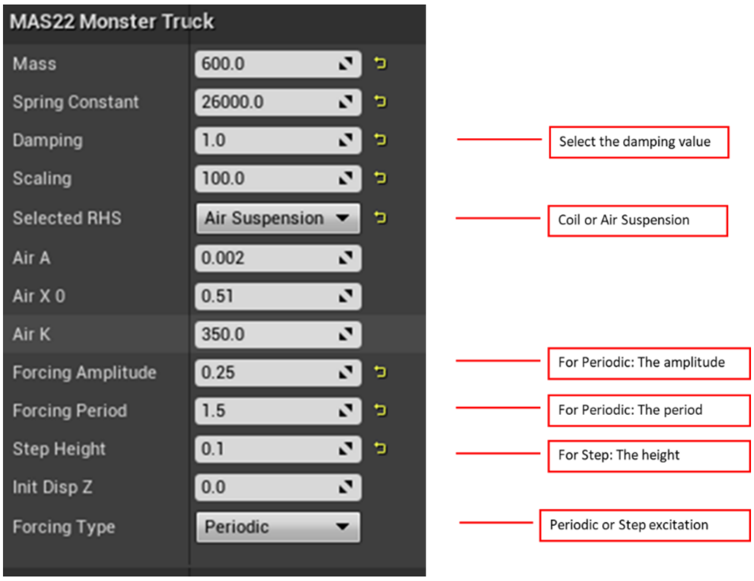
3.1 The Model Parameters

Here we state the model parameters and indicate which we can change in a sensible investigation. We shall see their Unreal default values later

Body Mass	The Land Rover has a fixed mass (kg) but this can be slightly changed according to the number of passengers
Coil spring constant	This is fixed by design so is hard to justify changing this
Air spring parameters	Again, fixed by design, so leave alone
Damping	Yes, this can be changed, since this can be done on real shock absorbers
Forcing Amplitude	A key parameter which we can change. It represents the height of a regular series of bumps in the road.
Forcing Period	A key parameter which we can change. It represents the distance between a regular series of bumps in the road.
Step height	A key parameter which we can change. It represents the height of a sudden disturbance such as when the Land Rover drives up the kerb.

3.2 The Unreal-Editor Interface

There are two parts to the UI, the first refers to the model(s) and parameter selections. The second refers to the solver engine. Here's the first part, you will only need to change stuff here.



4 Suggested Investigations

Here are some ideas. You could choose one to get started. Then you could plan your own investigations within the context of a group **learning conversation.**

4.1 Comparing the Coil and Air Spring response to Periodic Excitation

(1) First select the **Coil** spring. You will change the forcing period and measure the resulting Land Rover body oscillation amplitudes and so investigate the graph presented above in 2.2. This is a good place to start. The data will come from (i) the HUD and (ii) the auto-generated Octave files **MT.m** in the directory **OctavePlots** within the engine directory. For each value of forcing period, add your data to the Octave script **Moonster_Reonance_0902.m**. Hopefully your data will agree with theory.

(2) Now repeat using the same values of forcing period with **Air Suspension** selected. The result will not (and should not) agree with theory (which is only relevant for the coil spring).

So, you have different results. So, compare, e.g., is the air suspension more or less 'stiff' than the coil suspension in this case. You may need to research what the *stiffness* of a spring is.

4.2 Comparing the Coil and Air Spring response to a Step Excitation

(1) Choose a **Stepped** forcing type and investigate steps of height in a range 0.1 – 0.5 for the coil spring. Measure the **period** of the oscillations from each Octave plot. You might want to snip and paste each plot

(2) Now repeat for the Air Suspension. Remember the Air Suspension has a maximum displacement of 0.5, gathering **period** data again.

Now make plots of step height (horizontal) and period (vertical for the two spring types. You can use the generic **plotit** script, appropriately amended (axis labels, titles).

Compare plots for both spring types, how does period depend on step height? The air suspension plot will be of particular interest; look carefully at its shape, especially as the step approaches 0.51. Conclusion?

4.3 Investigate the effects of Damping

(1) Perhaps use the **Stepped** forcing type (with one value for step) and change **damping** in the range 0.0 – 10.0. You could apply this to both Coil and Air Suspension and see what you find. Keep all your Octave plots.

A classic *measure* of damping effects is to measure the time for the initial displacement to be reduced by a factor of 1/3, but you could choose another measure, such as ½.

So, you could make a summary plot of how this time changes with amount of damping, and then draw a conclusion. You can use the generic **plotit** script, appropriately amended (axis labels, titles).

(2) Perhaps use **Periodic** forcing and repeat all the above.

4.4 Passenger load, Ride and Comfort.

The value of the mass provided as default was for two adults. A Land Rover Defender 110 can take 5 people and a load of sheep in the back. How does this additional mass change things? You could use periodic forcing for a single period, or step forcing for a single step height.

You can use the generic **plotit** script, appropriately amended (axis labels, titles).