

It is essential that you have completed the previous two tutorials on mechanisms from this series before starting this one. The part and assembly files for this model can be downloaded from the internet and can be found at <http://www.staffs.ac.uk/~entdgc/ProeDocs> in the Dynamics section. Save all 7 parts and 1 assembly to your working directory.

Open the assembly and you will see that the mountain bike has already been assembled for you and operates correctly as a mechanism. Check this out now by using the DRAG command. Some points worth noting are:-

1. The method used to model the frame of the bicycle.
2. The front wheel is the first part assembled and is effectively locked to ground so it doesn't move.
3. The rear wheel is assembled using a planar joint so it is free to move backward and forward as the suspension flexes since the wheelbase will change.



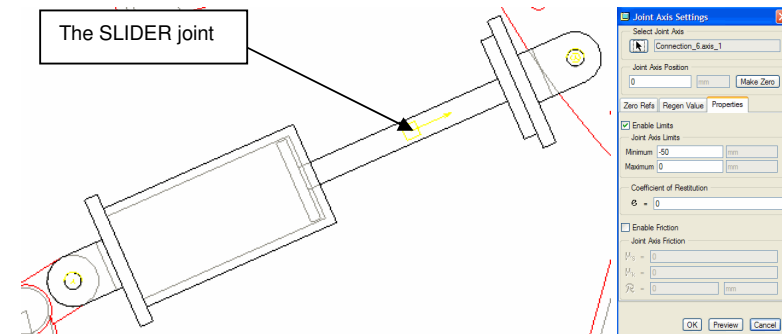
**Figure 1 : The Bike**

Review all these features now and ensure you understand how they were achieved by referring to the earlier mechanism tutorials. You may even prefer to create your own assembly file and assemble your own cycle to ensure you fully understand the process.

## Joint Definitions

As you drag this mechanism you will probably have noticed that the damper joint moves too far. The parts can actually move so they pass through each other. This means the suspension travel is much too large. Any joint in Pro Engineer can have its movements restricted – here's how.

First use the DRAG tool to position the mechanism such that the damper is near one extreme of its travel as shown in Figure 2 (you may want to switch to hidden line display to see this). Then choose MECHANISM > JOINT AXIS SETTINGS and pick the SLIDER joint to define its settings. Press the MAKE ZERO button to define the current position as the zero location. Next click on the Properties tab in this dialog and tick Enable Limits and enter the values for maximum and minimum travel. This damper has a range of 50mm and the travel is in the opposite direction to the joint so the maximum value will be 0 and the minimum -50.



**Figure 2 : Joint Limits**

Now if you DRAG the model the movement should reflect a real bike frame.

## Springs

Although the bike moves correctly there are some elements of the bike suspension that are missing. The first of these is the spring. It is possible to model a spring using the HELICAL SWEEP command and this would look like a spring. For the analysis of mechanisms we need a spring that reacts correctly like a spring applying forces as it is compressed. This type of spring can be defined in mechanisms. Make sure you are in mechanism analysis mode (APPLICATION > MECHANISM) then choose

MECHANISM > SPRINGS and create a NEW spring. From the dialog box which appears (Figure 3) you will see there are two ways of defining the spring – on a joint axis or point-to-point. We will use the point-to-point option so choose this then pick the 2 points that have already been created in the model called SHOCKTOP\_POINT and SHOCKBOTTOM\_POINT. One of the advantages of using point-to-point is that Pro Engineer will create a visual representation of the spring – untick the Default option for the icon and type a diameter of 36.

Finally we have to define the dynamic properties of the spring. The force created by a spring is directly related to the compression of the spring (Pro Engineer has no facility for variable rate springs). Most springs start of with some pre-compression so the actual force from a spring is given by the formula  $Force = k * (x - U)$  where K is the spring stiffness (N/mm) and U is the free length of the spring (mm). Enter values of 190 for k and 125 for U. Choose OK to see the spring icon which may not be perfect but it is a reasonable representation

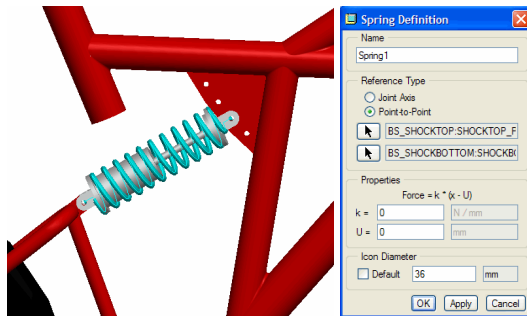


Figure 3 : Spring Settings

## Dampers

The second missing element is the damping action which is created in a similar manner. Choose MECHANISM > DAMPERS and create a NEW damper. From the dialog box which appears (Figure 4) you will see there are three ways of defining the damper. Though it is less important in this case we will be consistent and use the point-to-point option so choose this then pick the same two points SHOCKTOP\_POINT and SHOCKBOTTOM\_POINT. The damping force created by a damper is related to the velocity of movement of the damper multiplied by a damping constant C (Pro Engineer has no facility for variable rate dampers or

different rates for compression and bump). Enter a value of 1.1 for the damping constant C. Choose OK to finish the definition.

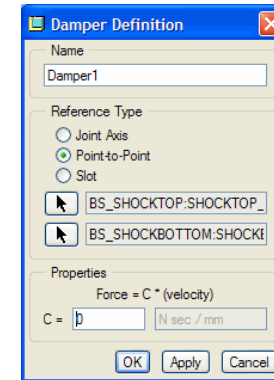


Figure 4 : Damper Settings

## Materials

Closely related to the gravity settings are the material properties. The default density assigned by Pro Engineer is 1 tonne/mm<sup>3</sup> which means parts will be extremely and have very high inertia – they will be difficult to move! To set the correct density values choose MECHANISM > MASS PROPERTIES.

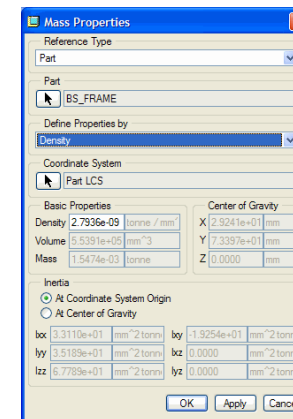


Figure 5 : Material Density

Pick one of the parts in the mechanism (say the frame) and change the Define Properties by to Density. The DENSITY field should now be editable and you can type in a value in tonne/mm<sup>3</sup>. (Aluminium 2.7936e-9, Steel 7.82708e-09, Nylon 1.20014e-09). Change the value to aluminium for ALL the parts in this assembly. Don't forget to do all the parts otherwise the later calculations will not work correctly.

## Gravity Forces

If the mechanism is to react correctly gravity must be specified. This is easily set using MECHANISM > GRAVITY. Note the units required in this dialog mm/sec<sup>2</sup> so the normal (earth) value is 9810. The direction for this model is -1 in Y.

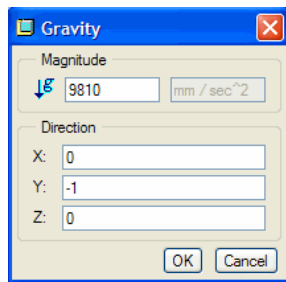


Figure 6 : Gravity

## Initial Conditions

We are soon going to start to analyse this mechanism soon. To do this it is useful to have a known starting position called an Initial Condition in Pro Engineer. Initial conditions can specify the start position, velocity and acceleration of a mechanism. We are only interested in the start position which is defined by a snapshot. Drag the mechanism so that the damper is fully compressed and save this as a snapshot called DamperMin as

described in the earlier Basic Mechanisms tutorial (hint : use the icon in the DRAG dialog). Now choose MECHANISM > INITIAL CONDITIONS to define the start conditions. Create a NEW condition and the dialog in Figure 7 will be displayed. Call the condition COMPRESSED and select the snapshot you have just saved.

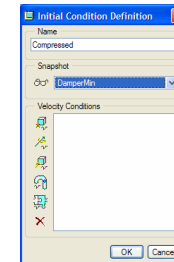


Figure 7 : Setting an Initial Condition

Whilst you are here drag the mechanism so that the damper is fully extended and create a second snapshot called DamperMax. Then create a second NEW condition called EXTENDED and select the second snapshot you have just saved. Click OK to finish.

## Static Analyses

Now we are ready to start to analyse the model. The first type of analysis we will investigate is called a static analysis. This type of analysis will take into account all of the forces on the mechanism and find the equilibrium position. Let's start with a simple situation – the bike is standing still with no rider seated just supporting its own weight. In this situation you would expect that if the suspension is designed correctly the damper would be stretched to its maximum limit. Let's see how we can prove this.

Choose MECHANISM > ANALYSES and create a NEW analysis. Change the settings in the dialog to reflect those in **Error! Reference source not found..** You will need to change the Name, Type, Initial Configuration and Tick Enable Gravity in the Ext Loads tab.

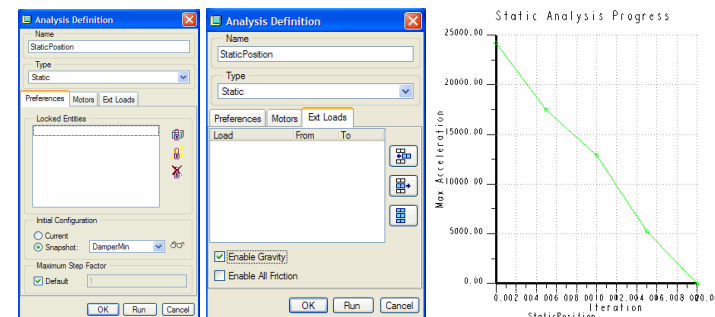
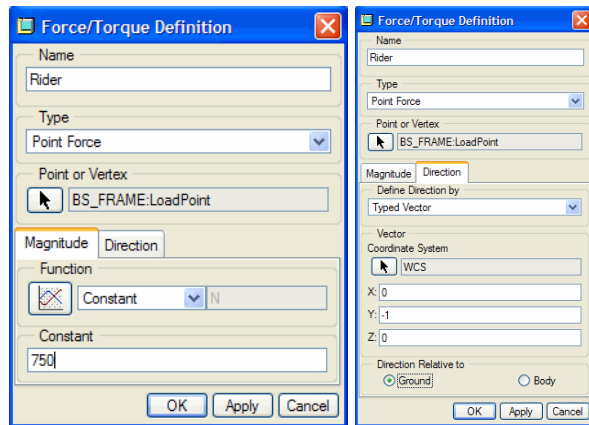


Figure 8 : Defining a Static Analysis

If you press RUN now you should see the model gradually changing the position as the program iterates the equilibrium position. The graph that appears also reflects the program ‘homing’ on the correct position – if the final point is plotted at a Y axis value of zero you know the model has found the equilibrium. If you look carefully at the damper you should see that it has stretched to its maximum length as you would expect. Press OK to finish this analysis.

## Loads

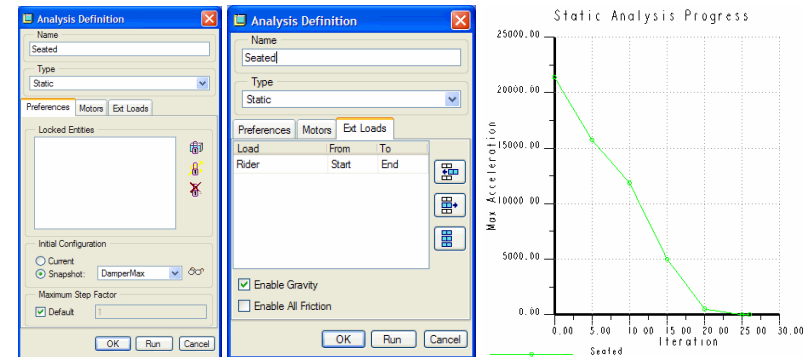
Let’s use a similar analysis to find out how much the damper would compress when a rider sits on the seat. The rider weighs 12 stone/168lbs/76Kg so the force which will be applied to the seat will be 750N. This load can be created using MECHANISM > FORCE/TORQUE and creating a NEW force.



**Figure 9 : Creating Forces**

Call the force Rider and apply it as a Point Force picking the predefined point on the end of the seat stem as the location. The force will be a Constant 750N. Check the Direction tab and ensure the vector is set to -1 in Y.

Now create a new static analysis just like you did before. Call this analysis SEATED and set all parameters just like the STATICPOSITION analysis but also make sure the RIDER force appears in the Ext Loads tab. Run the analysis.

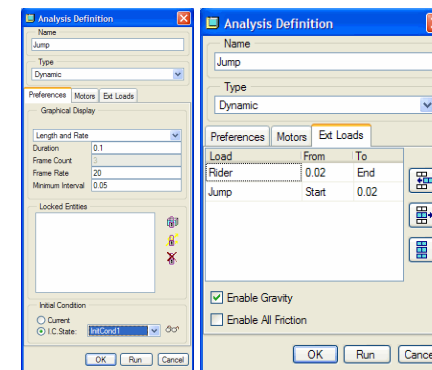


**Figure 10 : Forces in a Static Analysis**

Just like the last analysis the model should home in on the equilibrium position but you would now expect the damper to be just a little compressed – zoom in to the damper to see this is the case.

## Dynamic Analyses

A second type of analysis will also be useful in designing this bike. If the rider goes over a large jump a correctly designed suspension should compress but not reach its full travel or ‘bottom out’. Let’s test this using a dynamic analysis. The parameters for this test are that a force of 8 times the rider’s weight will be applied for 0.02 sec and then a constant load equal to the rider’s weight will be applied.



**Figure 11 : Dynamic Analysis**

To prepare for this analysis create a second force called JUMP which is 8 times the RIDER load (6000N).

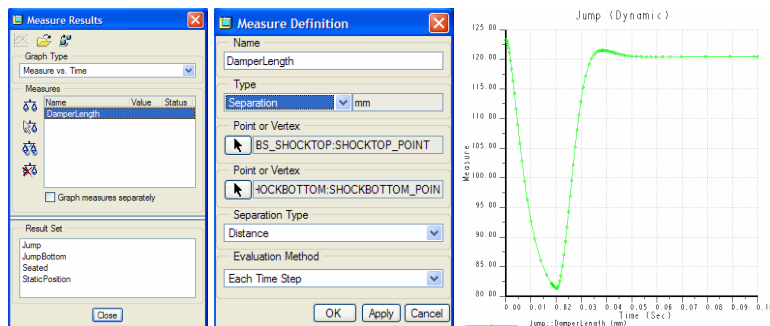
Now create a new analysis called JUMP. Change the type to DYNAMIC and the duration to 0.1 then switch to the EXT LOADS tab and add both the RIDER load and the JUMP load over the durations shown in Figure 11.

Run the analysis and you should see the damper compresses to near its full extent then bounces back before settling back to normal riding position.

## Measures

Watching the action on the screen is not very accurate. You may need to know more precisely some value from the mechanism such as how the damper length varies over the duration of the dynamic analysis. This is known in Pro Engineer as a measure. Measure are available for lots of things such as velocity, acceleration, forces as well as distance.

To create a measure choose MECHANISM > MEASURES. In the dialog choose to create a new measure. Type a name of DAMPERLENGTH and a type of SEPERATION picking the SHOCKTOP\_POINT and SHOCKBOTTOM\_POINT. Click OK on the Measure Definition dialog. Now highlight the DAMPERLENGTH measure and the JUMP result set and the small graph icon at the top of the dialog should activate. Press this icon to see the results.



**Figure 12 : Creating a Measure**

You could experiment with the spring and damper definitions to see the effect on this analysis – don't forget to RUN the analysis after you make each change.

## Review

So what should you have learnt?

- How to define joint limits, springs, dampers and forces.
- How to create static and dynamic analyses.
- How to create measures.

Any problems with these? Then you should go back through the tutorial – perhaps several times – until you can complete it without any help.