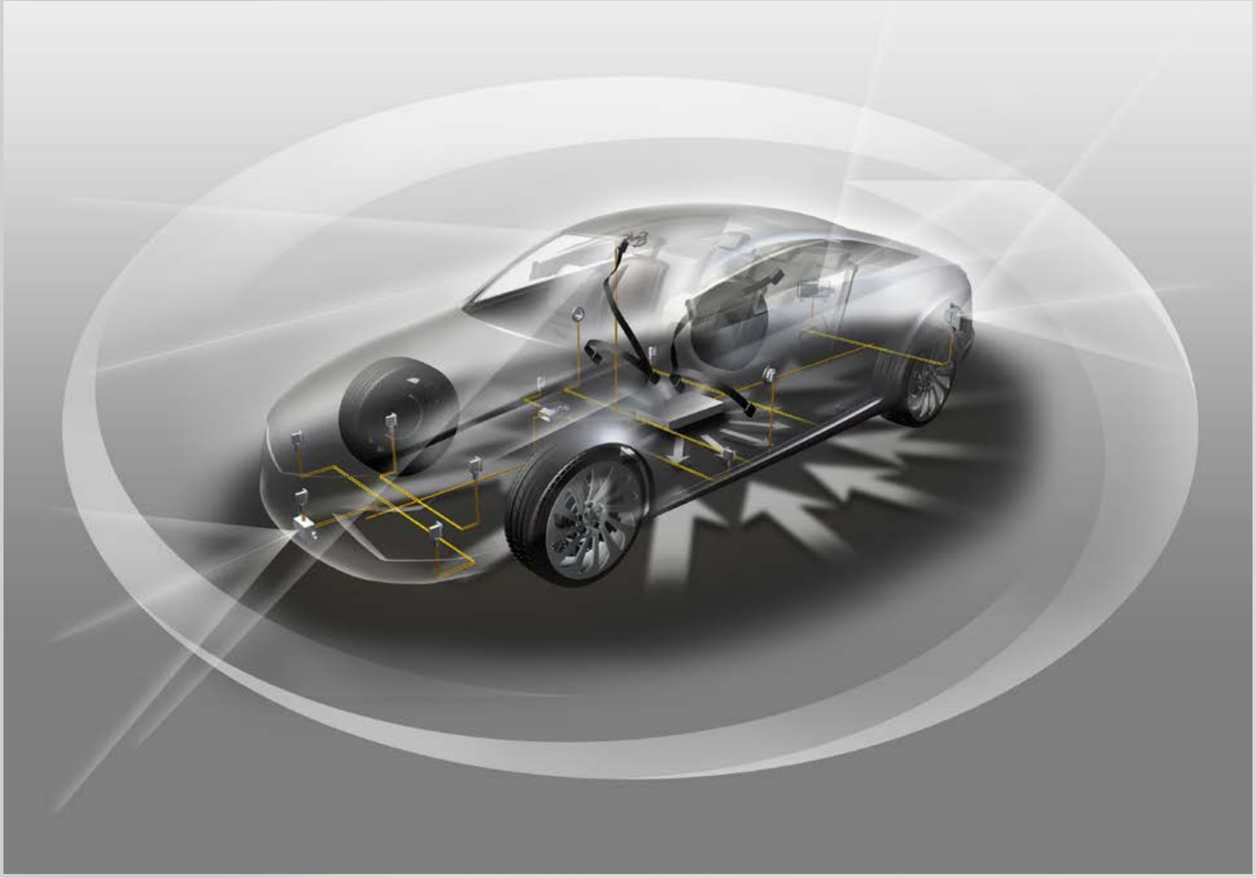
Section

4

HOW TO MODEL ALMOST

ANYTHING



Virtual Laboratory

PRODUCT DEVELOPMENT MANUAL

How to Model Almost ANYTHING

WRITTEN BY JORDAN COX

NOTICE OR RIGHTS

TRADEMARKS

ACKNOWLEDGEMENTS

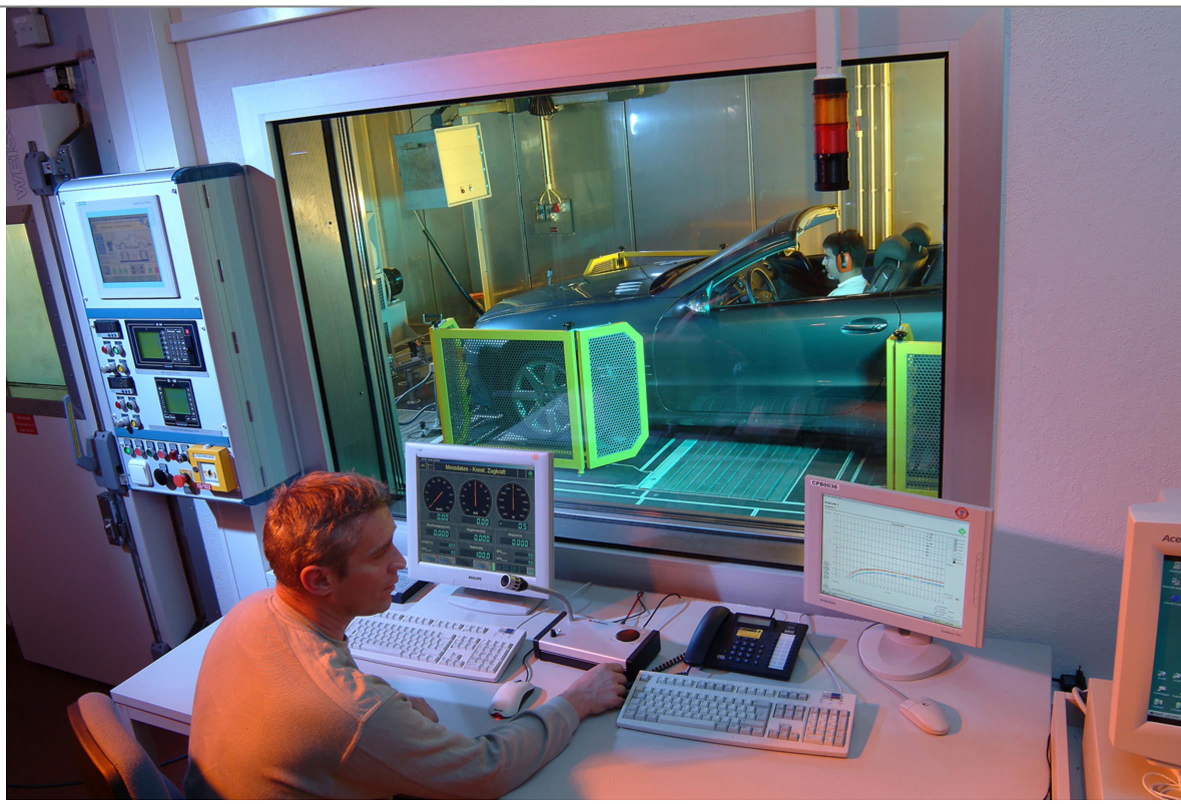
Scott Morris, Mark Fischer, Adam Haas, Ayora Berry

Section

4

A VIRTUAL LABORATORY

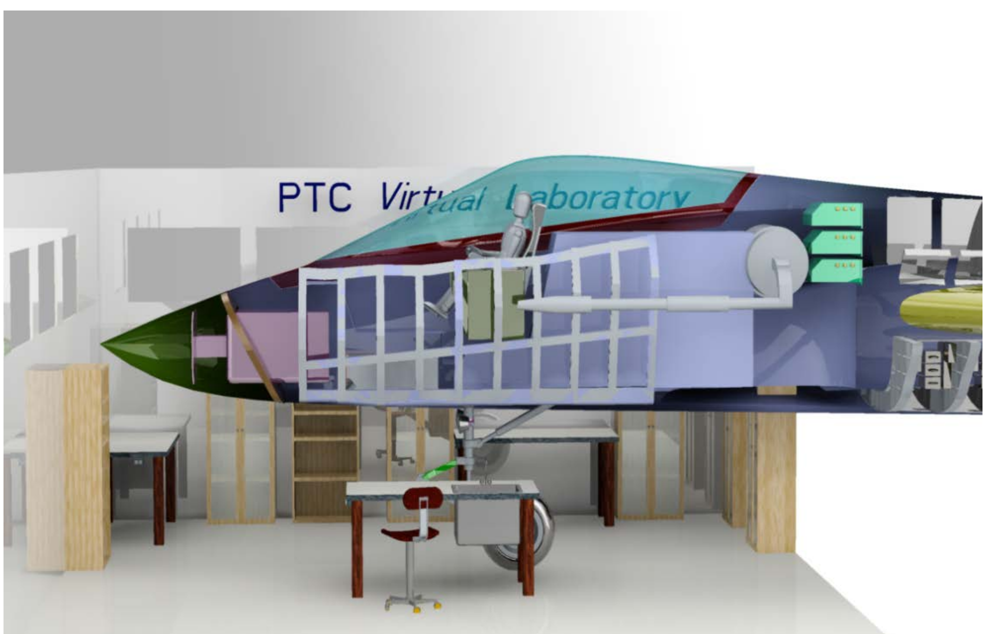
USING CREO TO SIMULATE THE REAL WORLD



An important part of product development is simulation. Creo makes it easy to simulate the real world. It becomes a virtual laboratory where all kinds of tests can be conducted without anyone getting hurt.

Creo was developed so that engineers and designers could do simulations and predict how a product or part would react to given loads and conditions. In this way, Creo becomes a virtual laboratory where experiments of all types can be created and performed.

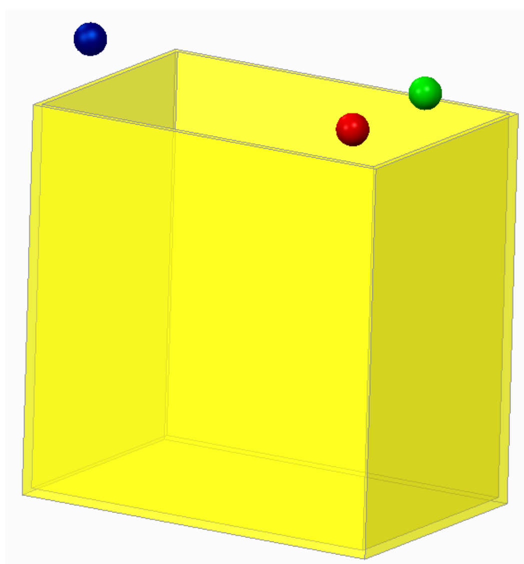
Creo is like a virtual laboratory where parts and products can be explored and tested. Even human factors like aesthetics and ergonomics can be explored using manikin models.



This virtual laboratory capability allows us to bring things into our virtual laboratory that we would have a hard time doing in real life, like driving a jet aircraft in to the lab. Not only is it possible to do experiments that you couldn't do otherwise, but the safety concerns are eliminated as well.

Most of the simulation that we will be doing in this workshop will be using the Mechanism application where motion can be simulated. There are other applications as well that allow forces and stresses to be calculated, in addition to heat transfer and flow dynamics.

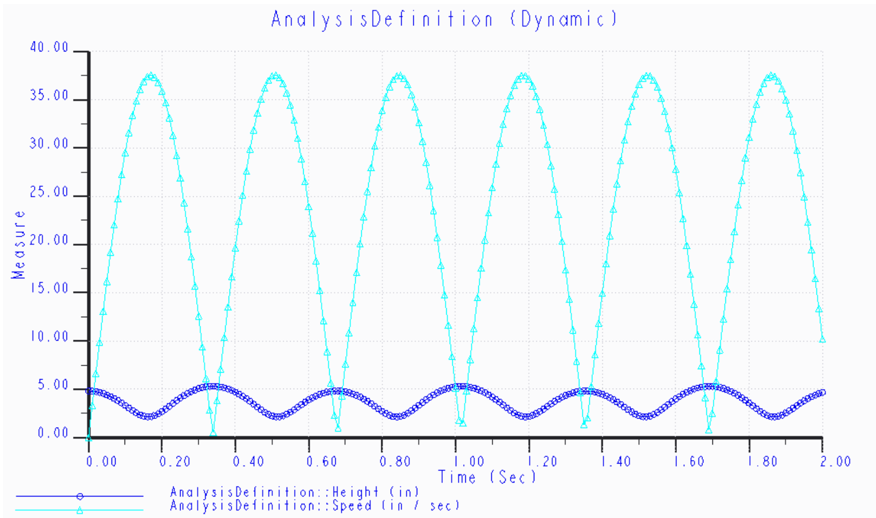
Let's begin by running a simple experiment with 3 rubber balls and a container that will let them bounce. We will change the level of gravity so that we can study the behavior of the bouncing balls on Earth, Mars, and the International Space Station.



*Find in the Appendix "**Exercise 10: Bouncing Balls Lab**" and follow the instructions to complete the exercise.*

COLLECTING DATA

Another important aspect of simulations is being able to collect data so that the performance of the product or part can be studied precisely. Creo allows data to be gathered and plotted so that it can be analyzed.



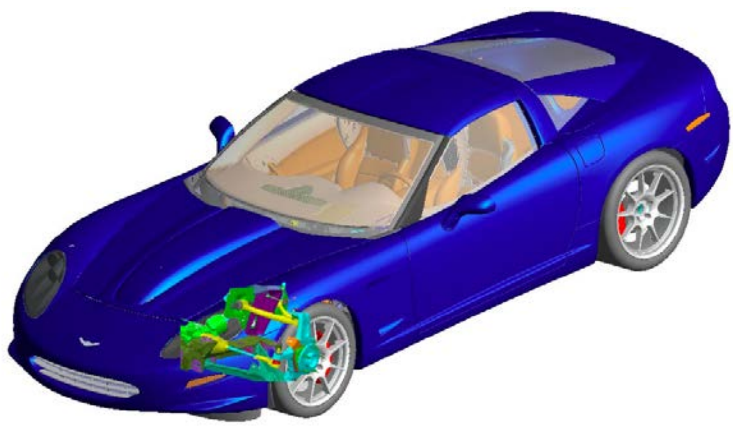
In the next exercise, we will explore the transformation of potential energy into kinetic energy and vice-versa. In this experiment we will identify points where we want to collect data and then identify the types of data we want to collect. We will also be able to compare the data while we are running the experiment.

*Find in the Appendix "**Exercise 11: Potential Energy Lab**" and follow the instructions to complete the exercise.*

Combining Creo with Mathcad

Creo provides many capabilities for simulating the real world. It is sometimes very helpful to couple the simulation capabilities of Creo with the "live" math and documentation capabilities of Mathcad.

In this exercise we explore the design of suspensions and how a mass-spring-dashpot system can model the behavior of a much more complex suspension system like a car.



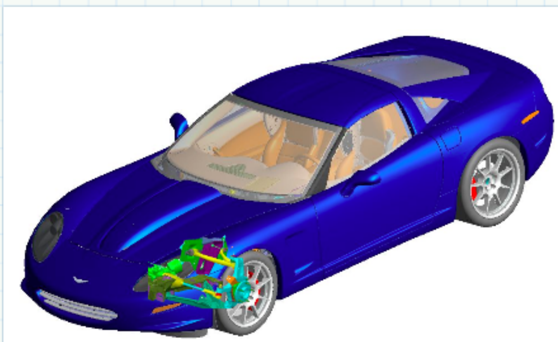
Creo can be used to create simple experiments to help design as well as to create the actual suspension. Mathcad allows the mathematics of the design to be captured in a "live" format so that the equations can be used anytime a new design needs to be created.

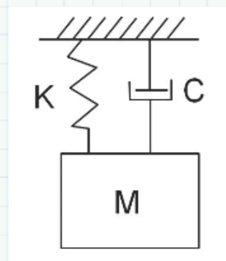
Homework set #1:

Designing your own automobile suspension

Objectives: *1. To learn how to use ordinary differential equations to predict an automobile's suspension and to design the suspension for a specified performance.*
2. To bridge the gap between mathematics and real applications

Description:
The suspension of a car can be modeled as a simple mass-spring-dashpot system. Assuming that the mass of the car can be lumped into a single mass and the springs and shock absorbers can be lumped as well into single units, the whole system can be simplified into a system with one mass, one dashpot (shock absorber), and one spring as shown.





Where: M = Mass of the car, C = viscous damping in the suspension, and K = the springs in the suspension system. Doing a sum of forces produces the following equation:

$$\sum F = 0 = M\cdot\frac{d^2}{dt^2}y(t) + C\cdot\frac{d}{dt}y(t) + K\cdot y(t)$$

Mathcad is like an electronic engineer notebook. It is very effective since all equations are built in natural math notation and are live so that they can be used as documentation but also as a worksheet equation. Units can also be assigned to values and Mathcad keeps track of the units and does unit conversions automatically.

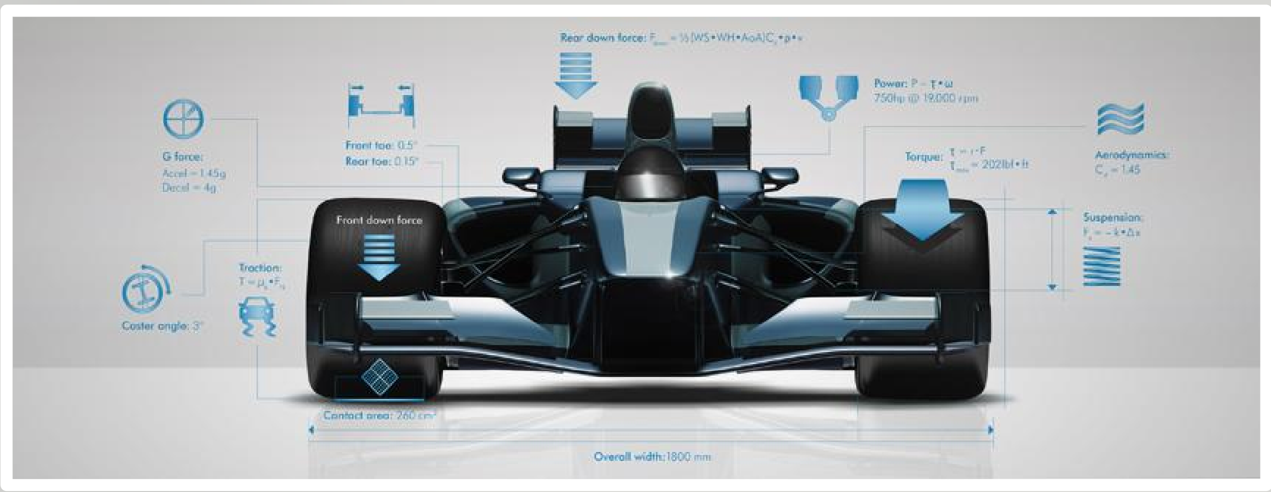
*Find in the Appendix "**Exercise 12: Mass-Spring-Dashpot Lab**" and follow the instructions to complete the exercise.*

Section

4

HOW TO MODEL ALMOST

ANYTHING

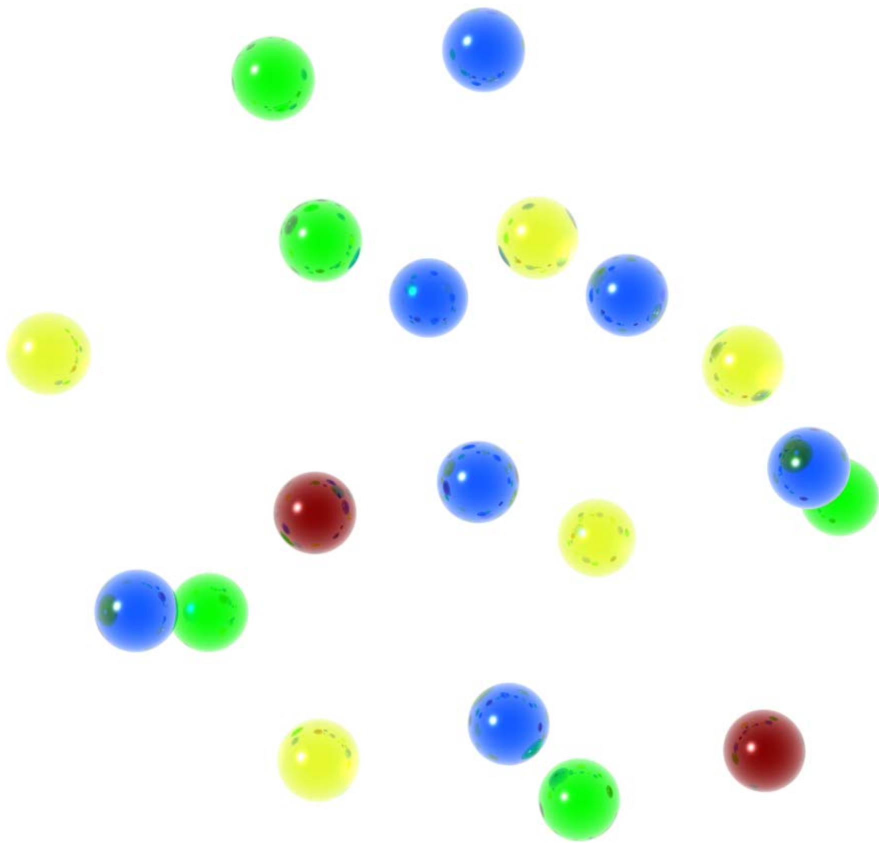


APPENDIX

Exercise 10: Bouncing Balls Lab

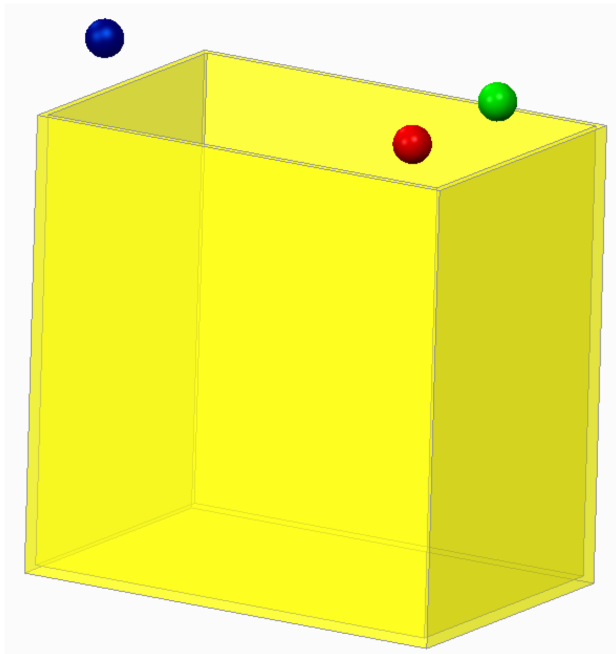
Big Idea: Gravitational attraction and conservation of energy during the bouncing ball collisions.

Everyone has experienced the force of gravity and felt it pull you towards the center of the earth. The force of gravity causes balls to be drawn toward earth thus creating kinetic energy because of the motion of the balls. When the balls encounter the floor or ground they experience a collision. The energy is conserved either through transforming it to heat and sound or through the restitution of bouncing in the opposite direction. The extent to which the energy is conserved through bouncing is measured in the coefficient of restitution.



The closer the coefficient of restitution is to the value of 1 the better a ball bounces. The closer it is to the value of 0 the quicker its bounces die out. These effects of bouncing are properties of the materials the balls are made from and can be modeled using Creo's virtual lab capabilities.

Activity 1: Learn about gravity and the coefficient of restitution.



Using the bouncing balls virtual laboratory you will explore gravity and the coefficient of restitution and learn about how they interact. You will learn how to explore different gravity fields and different materials' coefficients of restitution.

Let's begin by defining potential and kinetic energy. Potential energy is a measure of the stored energy in a system. There are many forms of potential energy, but the most common is associated with gravitational fields. When a ball is placed above the floor, there is the potential for it to drop to the floor. The energy is the result of the gravitational forces which pull the ball toward the center of the earth. The amount of potential energy is proportional to the height above a reference point such as the floor. It is easy to create an equation that represents potential energy.

$$PE = \rho g h$$

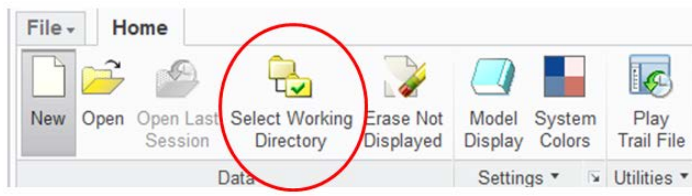
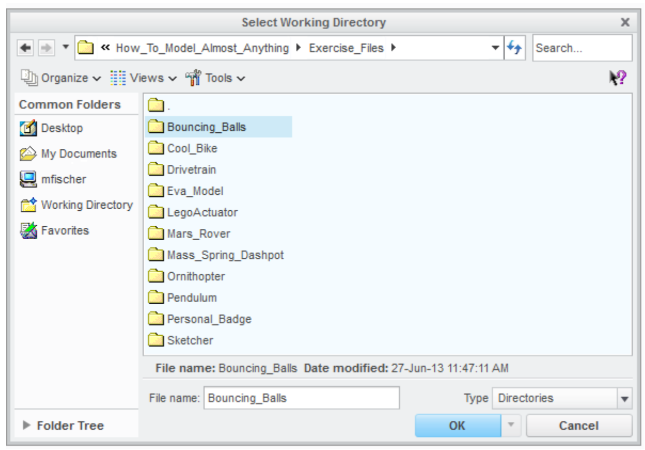
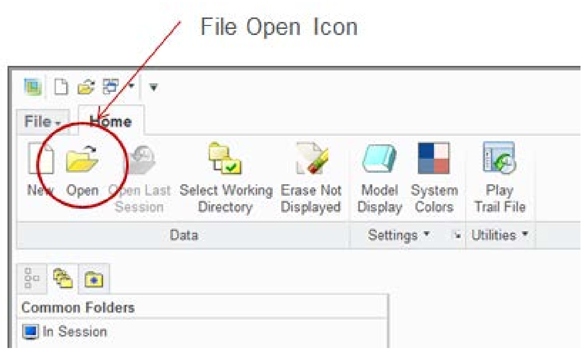
Where ρ is a number used to keep the units correct and g is the gravitational constant, and h is the height above the floor or ground.

Kinetic energy is energy associated with movement. The faster something is moving, the more kinetic energy it has. Once the ball hits the floor and bounces we can measure the coefficient of restitution by measuring the velocity before and after the collision.

$$C_R = \frac{V_{after}}{V_{before}}$$

This means the coefficient of restitution is a percentage.

Let's begin exploring gravity and bouncing through a virtual lab.

<table>
<tr><th colspan="2">GRAVITY & BOUNCING</th></tr>
<tr><td>Open Creo Parametric 2.0 and click the icon called Select Working Directory to set the folder in which you will be working.</td><td>
</td></tr>
<tr><td>Navigate to the folder called "Bouncing_Balls" and click OK.</td><td>
</td></tr>
<tr><td>Now click on the Open icon to open the file: "balls.asm". Double click on the file or select it and click Open.</td><td>
</td></tr>
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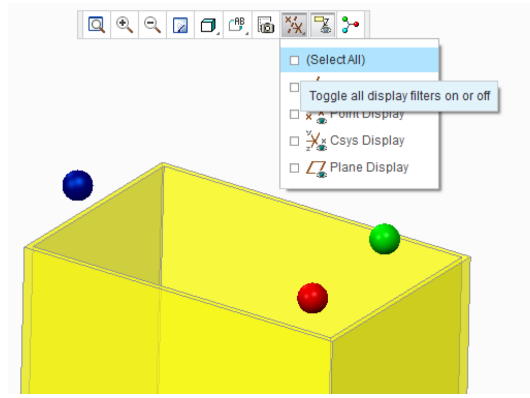
<table>
<tr>
<td>Now turn off the display of the datums by clicking on the datum display tool and making sure all of the boxes are unchecked.</td>
<td>
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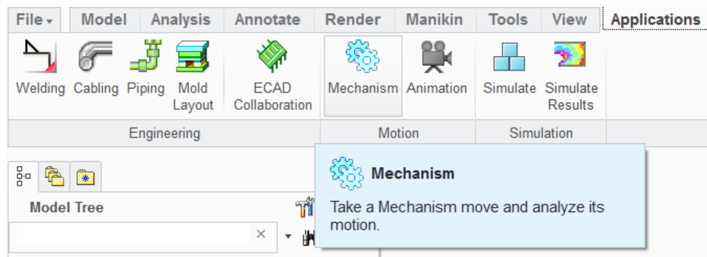
<tr>
<td>Go into the Mechanism Application.

So click on the Application tab and then select Mechanism.</td>
<td>
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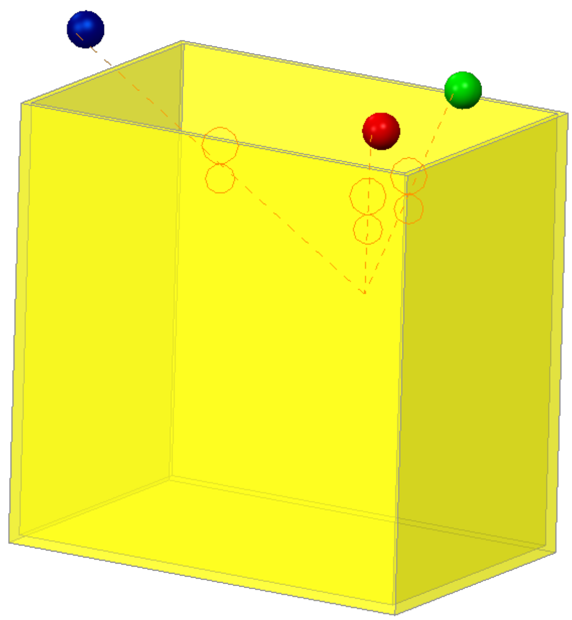
</tr>
<tr>
<td>Let's explore the model.

You will notice there are 3D contact connections between the three balls and the inner walls of the container as represented by the dashed lines.</td>
<td></td>
</tr>
<tr>
<td>Run an experiment by clicking on the Mechanism Analysis icon in the upper left menu.</td>
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<table>
<tr>
<td>

The Analysis Definition dialog box will appear.

Set the type of experiment to **Dynamic** by pulling down the **Type** menu and changing the type from **Position** to **Dynamic**. Also set the **Duration** to 10 and the **Frame Rate** to 10.

Then click on the **I.C. State** to use the initial conditions set up in the model.

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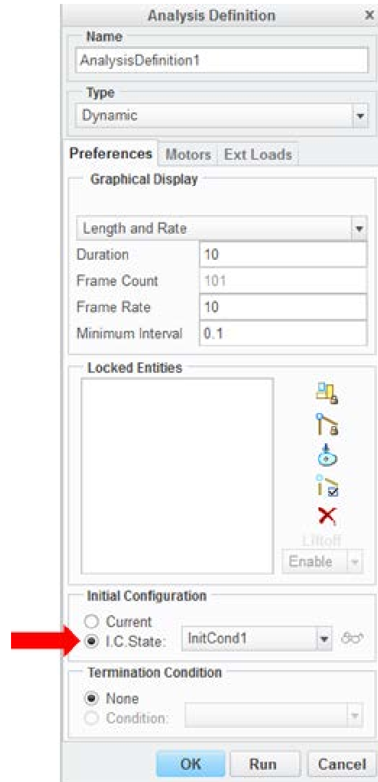

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Click on the **External Loads** tab and **Enable Gravity**.

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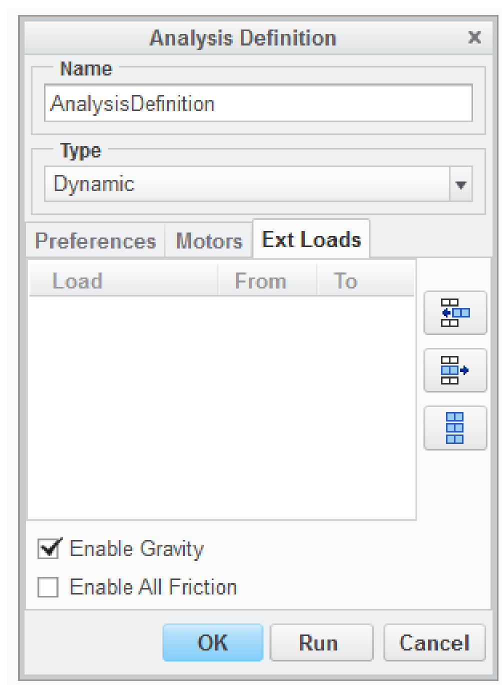

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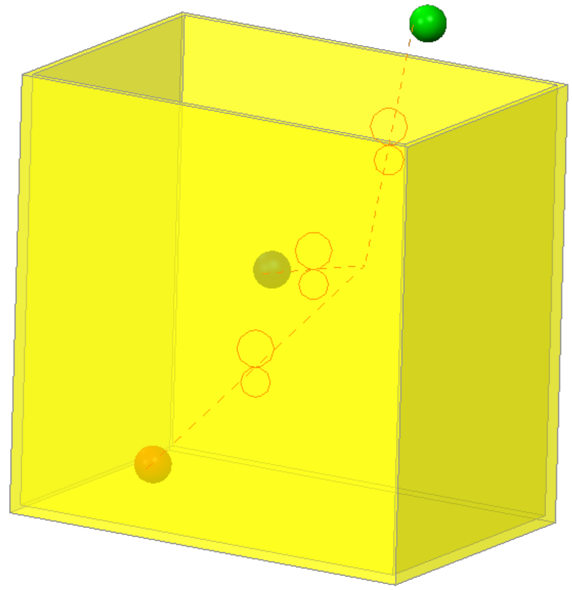
</table>

Click **Run** and watch the balls bounce.

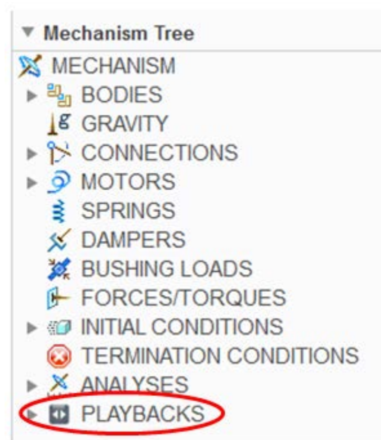
You will notice that the calculations slow down the motion when the balls are about to hit the walls. This is because it requires many more calculations once the balls get close to a collision.

After it finishes, click **OK**.

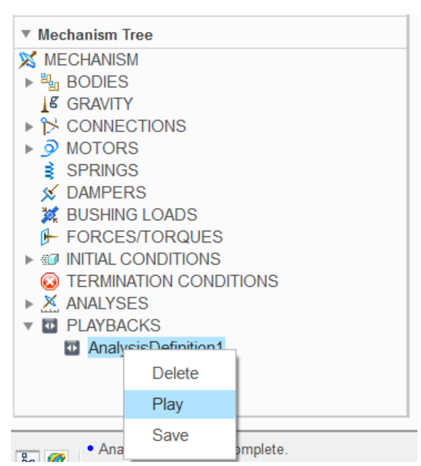


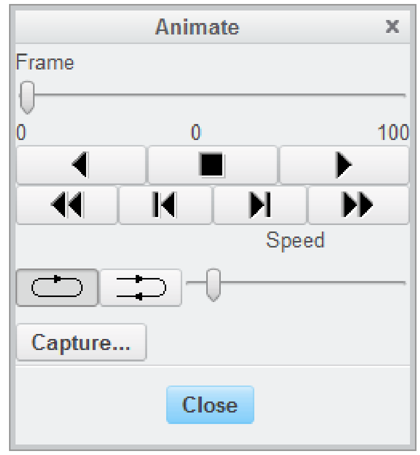
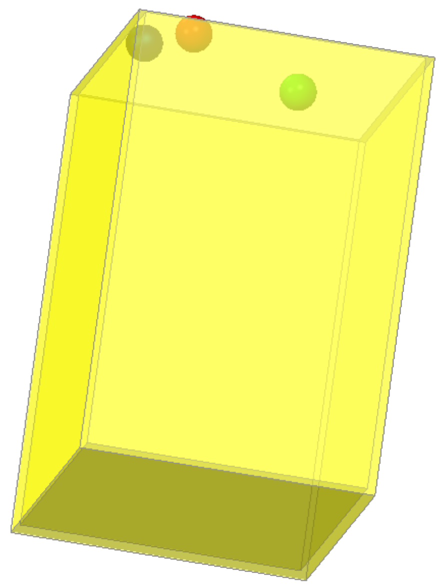
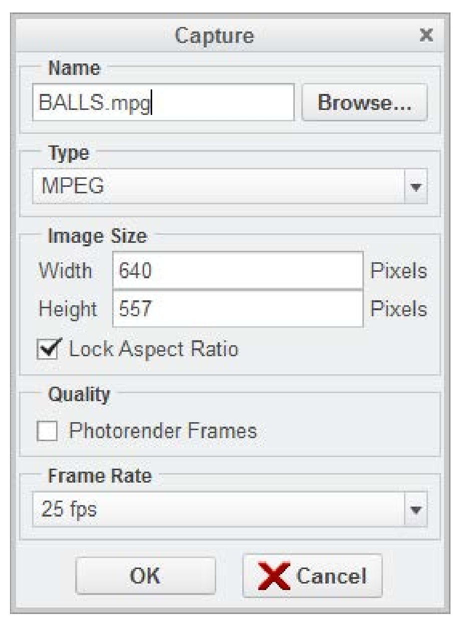
Let's replay the analysis.

Find the **Playback** entry in the **Mechanism Tree** on the bottom left of the screen.

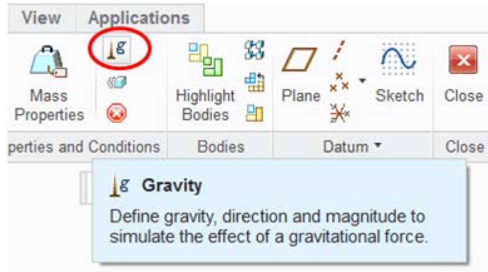


Expand the **Playback** entry and right-click on **AnalysisDefinition1** and select **Play**.



Use the **Animate** dialog box to replay the analysis. You can change the speed with the slider. This also allows you to rotate the model while it is playing back to see it from all angles.	 
Now let's create a video of this analysis. Click on the Capture button. You can change the parameters for the video or allow the default settings. Click **OK** to create the video file When you are done creating the video file click **OK**. Now click **Close** to finish the playback.	

<table>
<tr>
<td>Now let’s explore different gravity fields.

Find the Gravity tool in the upper menu and click on it.</td>
<td>
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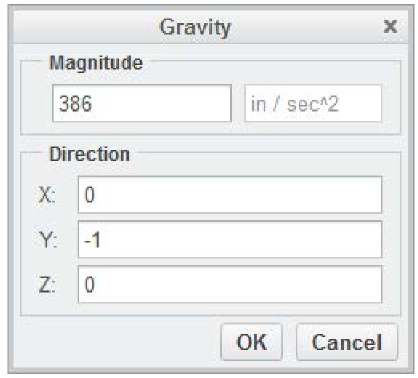
</tr>
<tr>
<td>Notice that the Magnitude of gravity is 386 in/sec^2 which if you divide by 12 is 32.174 ft/sec^2 so this is the force of Earth’s gravity.

Also notice the direction is in the negative Y direction.</td>
<td>
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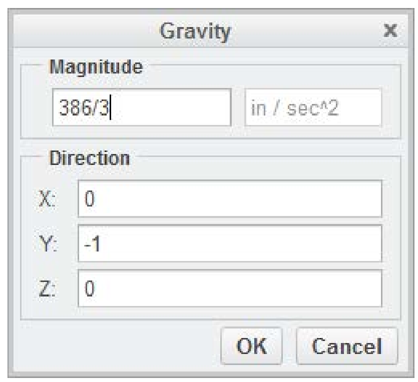
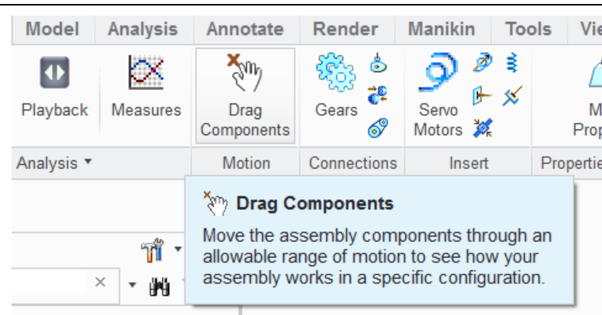
<tr>
<td>Mars’ gravity is 1/3 Earth’s gravity so type a divide symbol “/” and 3 and hit Enter.

Then click OK.</td>
<td>
</td>
</tr>
<tr>
<td>We want to reset the experiment so that the balls are at the top again.

The model was built with an initial condition and Drag Components allows us to reset to it. Click on Drag Components.</td>
<td>
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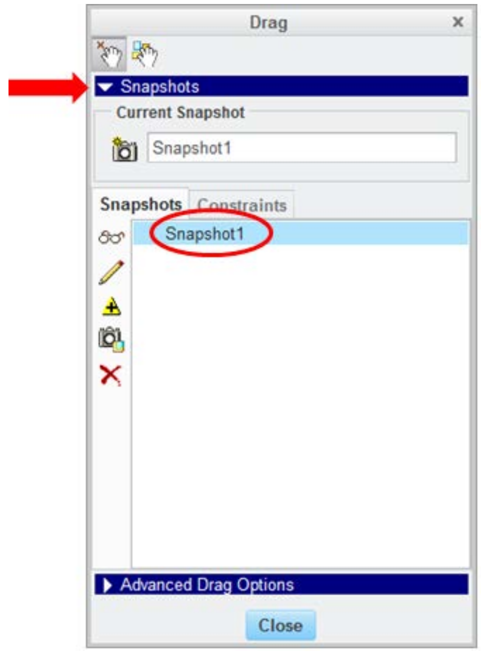
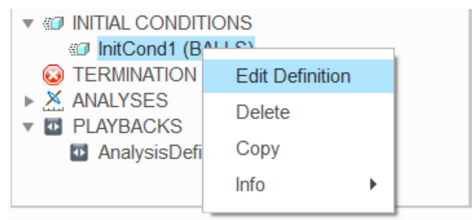
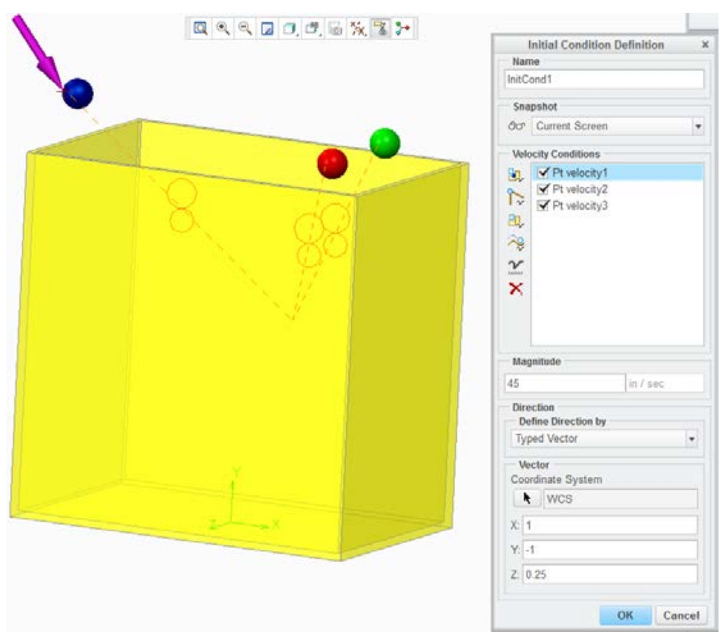
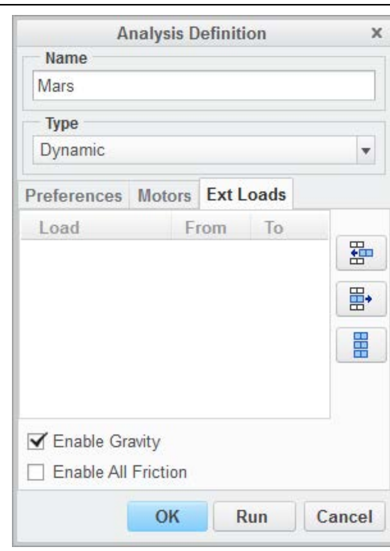
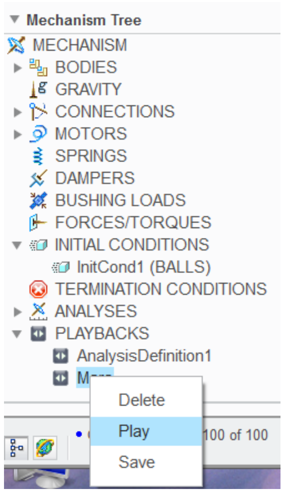
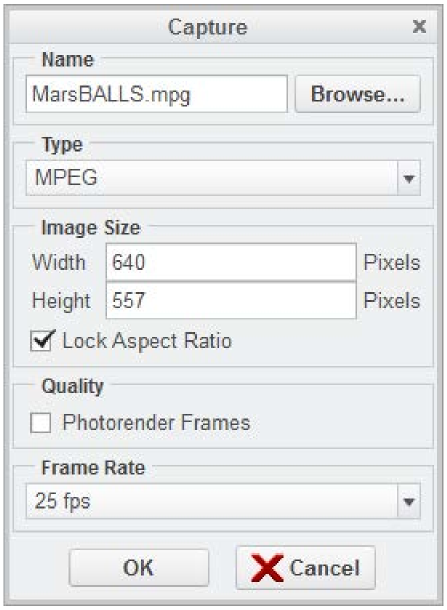
</table>

Expand the **Snapshots** arrow and then double-click on **Snapshot1**. This will reset the position of the balls. Click **Close**.	
Let's look at the initial conditions and see what they are set to. Find the **Initial Conditions** entry in the **Mechanism Tree** on the left and then right-click on **InitCond1 (Balls)** and select **Edit Definition**.	
Click on **Pt velocity1** to see the magnitude and direction of the initial velocity for the blue ball. You can check the initial velocity for each of the balls by clicking on the specific **Velocity Conditions** entries. ***Note***: *These initial velocities are only necessary so that we can observe the bouncing whether there is any gravity or not.*	

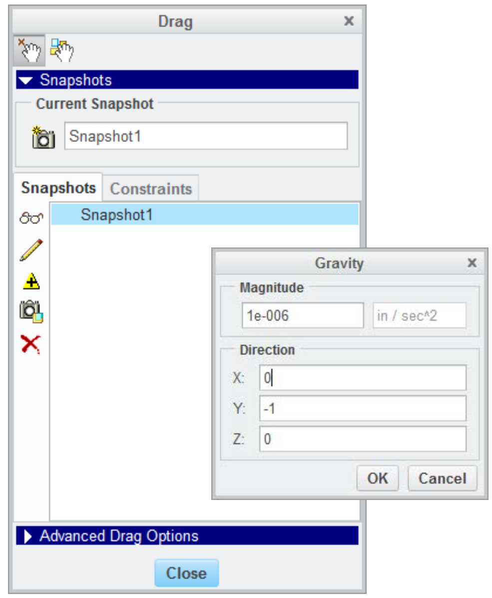
Click **OK** to close the dialog box.	
Find the **Mechanism Analysis** tool in the upper menu and click on it. Then change the **Name** of this analysis to **Mars**. Change the **Type** to **Dynamic**. And click on the **I.C. State**  button.	
Click on the **Ext Loads** tab and then **Enable Gravity**. Now click **Run**. Once it finishes click **OK**.	

Find the **Playbacks** entry in the **Mechanism Tree** and expand it to find the **Mars** analysis. Then right-click on it and select **Play**.	
Now let's create a video of this analysis. Click on the **Capture** button. Change the name to **MarsBalls.mpg** and then click **OK** to create the video file When you are done creating the video file click **OK**. Now click **Close** to finish the playback.	

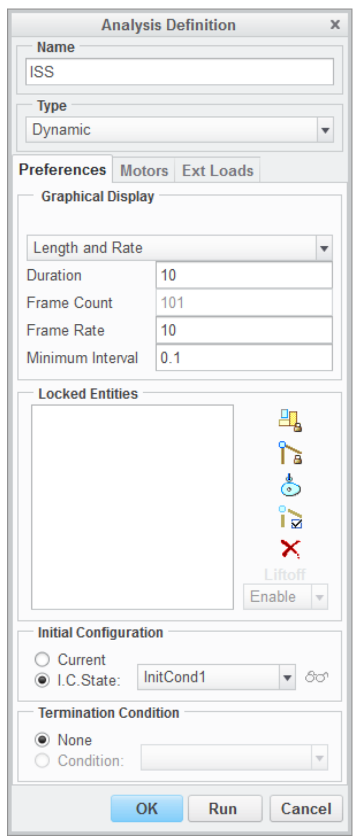
Let's change the gravity one more time and make an analysis and a video file then we will compare the three.

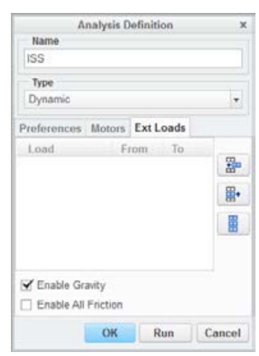
Using what you have learned, change the gravity to .000001 in/sec^2 which is the microgravity felt on the international space station.

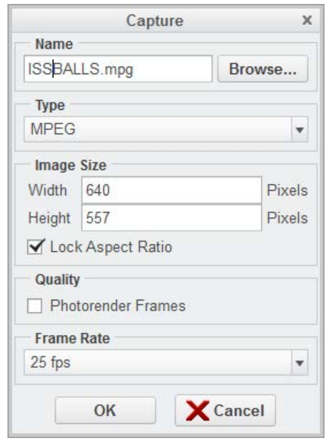
Reset the initial position of the balls using **Drag Components**.



Now create a new analysis called "**ISS**" and run it.





<table>
<tr>
<td>Finally find the Playback and create a video file called “ISSBalls.mpg”</td>
<td>
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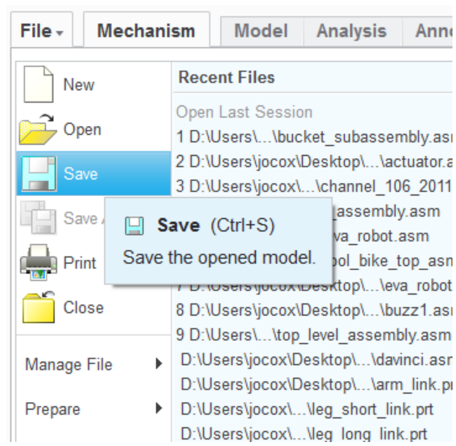
</tr>
<tr>
<td>Now save your assembly model by clicking on the File and then Save tabs.

Exit Creo.</td>
<td>
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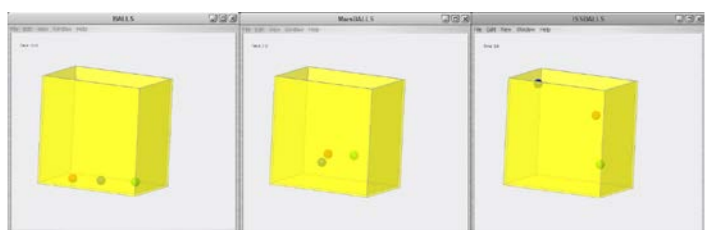
<tr>
<td>Now find all of the video files and open them in your local movie player so that you can view all of them at the same time.</td>
<td></td>
</tr>
<tr>
<td colspan="2">Congratulations, you have Completed this Exercise!</td>
</tr>
</table>

Exercise 11: Potential Energy Lab

Big Idea: Energy can be transferred between potential and kinetic energy using gravity and motion.

Energy comes in many forms. You can feel energy when you warm your hands around a campfire. When you climb a hill, you are increasing your potential energy. As you ski down the slope that potential energy is being converted into kinetic energy (energy due to motion).

Energy moves from one form to another. This movement of energy is important since it helps us do work. A car's engine converts chemical energy in the fuel and air into heat energy which is then converted into kinetic energy since the car moves down the road.

Activity 1: Learn about Potential and Kinetic Energy and how they can be exchanged.

Using the pendulum virtual laboratory you will explore potential and kinetic energy and learn about how they can be transferred back and forth. You will learn where the maximum potential energy is located and where the maximum kinetic energy is located.

Let's begin by defining potential and kinetic energy. Potential energy is a measure of the stored energy in a system. There are many forms of potential energy, but the most common is associated with gravitational fields. When a ball is placed on top of a hill, there is the potential for it to roll to the bottom. The energy is the result of the gravitational forces which pull the ball toward the center of the earth. The amount of potential energy is proportional to the height above a reference point such as the earth's surface. It is easy to create an equation that represents potential energy.

$$PE = \rho g h$$

Where ρ is a number used to keep the units correct and g is the gravitational constant, and h is the height above the floor or ground.

Kinetic energy is energy associated with movement. The faster something is moving, the more kinetic energy it has. Kinetic energy can also be measured using an equation.

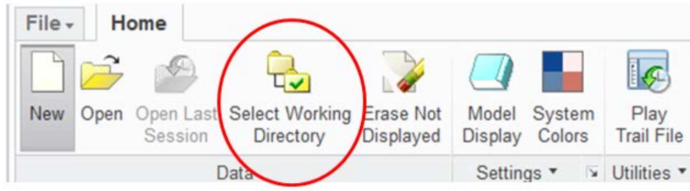
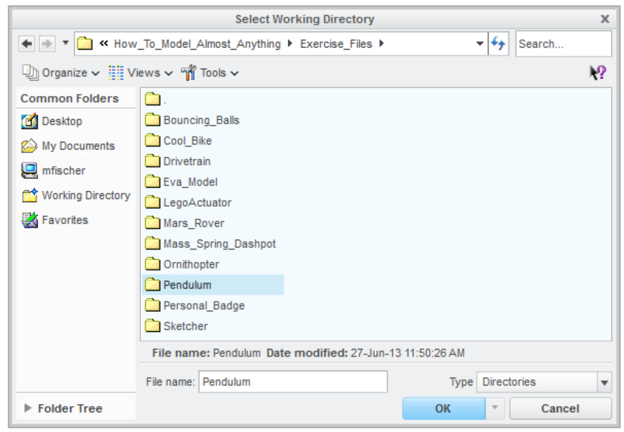
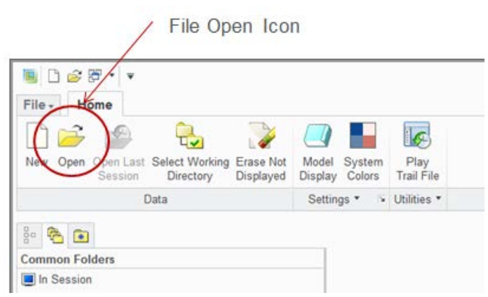
$$KE = \frac{1}{2} m V^2$$

Where m is the mass of the object and V is the velocity or speed at which it is moving.

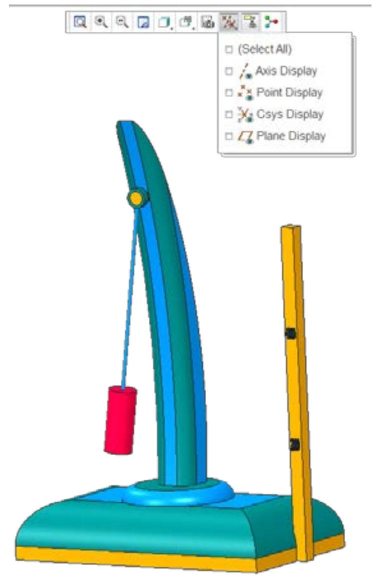
One of the most amazing aspects of energy is that it can be transformed from one form to another. For example, as the ball placed on the hill rolls down the hill it moves faster and faster as its potential energy is converted into kinetic energy. It loses its potential energy since its height above the bottom of the hill is being reduced and its kinetic energy is increasing because its speed is increasing. We can explore this connection between potential and kinetic energy with a simple experiment using a device called a pendulum.

A pendulum is a device that constantly changes potential energy in to kinetic energy and then converts kinetic energy into potential energy. We begin by lifting the weight on the arm up to a certain height which gives it a certain amount of potential energy. Once we release the arm, the weight begins to move downward picking up speed as it descends. It is converting its potential energy into kinetic energy. Once the pendulum reaches the bottom, all of its potential energy has been converted into kinetic energy. Now it begins to convert its kinetic energy into potential energy by lifting its arm a height above the bottom of its swing. A pendulum continues to cycle back and forth converting potential energy into kinetic and then vice-versa. Let’s try this out and do some measurements.

POTENTIAL & KINETIC ENERGY

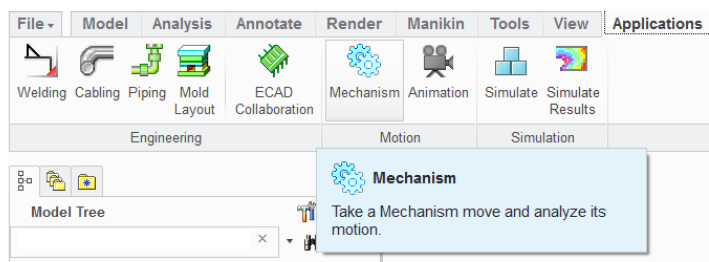
<table>
<tr><td>Open Creo Parametric 2.0 and click the icon called Select Working Directory to set the folder in which you will be working.</td><td>
</td></tr>
<tr><td>Navigate to the folder called "Bouncing_Balls" and click OK.</td><td>
</td></tr>
<tr><td>Now click on the Open icon to open the file: "pendulum.asm". Double click on the file or select it and click Open.</td><td>
</td></tr>
</table>

Now turn off the display of the datums by clicking on the datum display tool and making sure all of the boxes are unchecked.

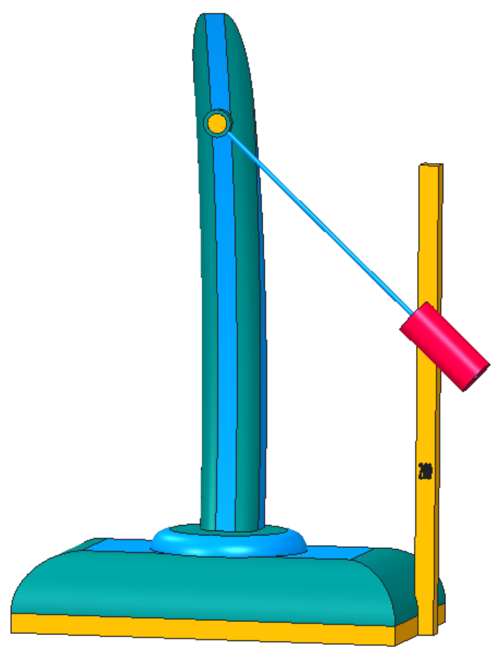


Go into the **Mechanism Application**.

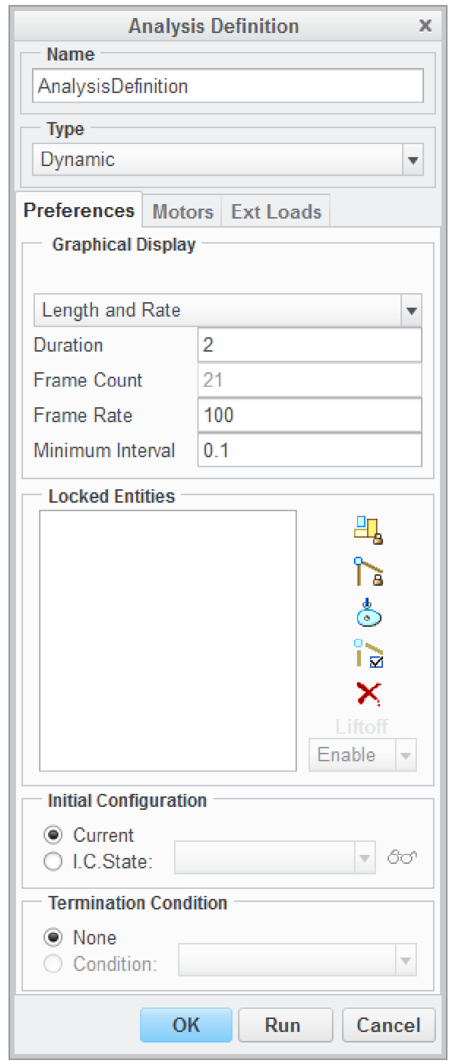
So click on the **Application** tab and then select **Mechanism**.

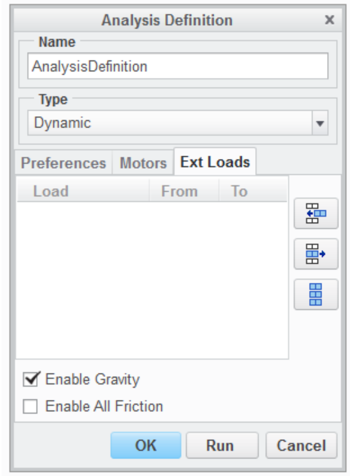


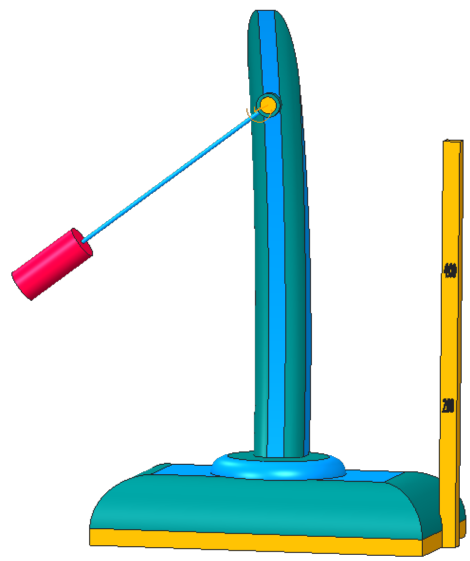
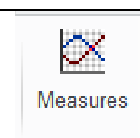
Raise the pendulum weight up to 4 units by pressing and holding down the **CTRL** and **ALT** keys on the keyboard and then left-clicking on the weight and dragging it.

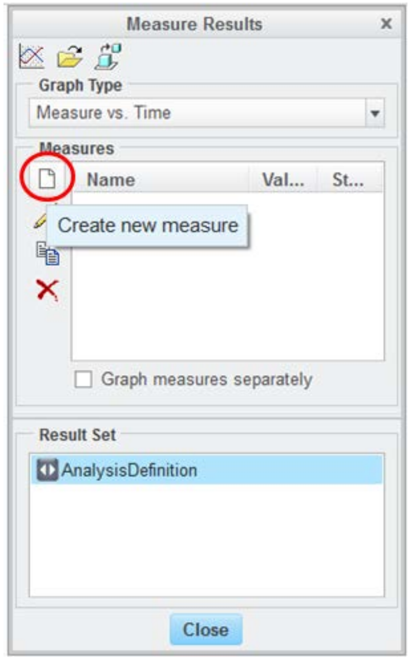
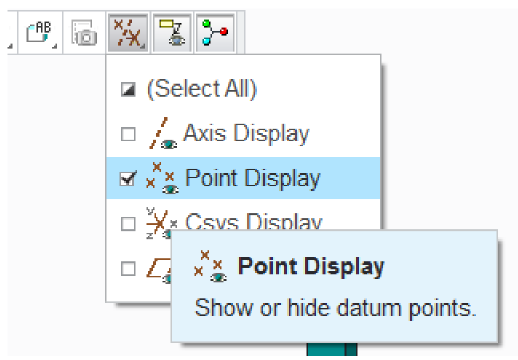


<table>
<tr>
<td>Run an experiment by clicking on the Mechanism Analysis icon in the upper left menu.</td>
<td>
</td>
</tr>
<tr>
<td>The Analysis Definition dialog box will appear.

Set the type of experiment to Dynamic by pulling down the Type menu and changing the type form Position to Dynamic. Also set the Duration to 2 and the Frame Count to 100.</td>
<td>
</td>
</tr>
</table>

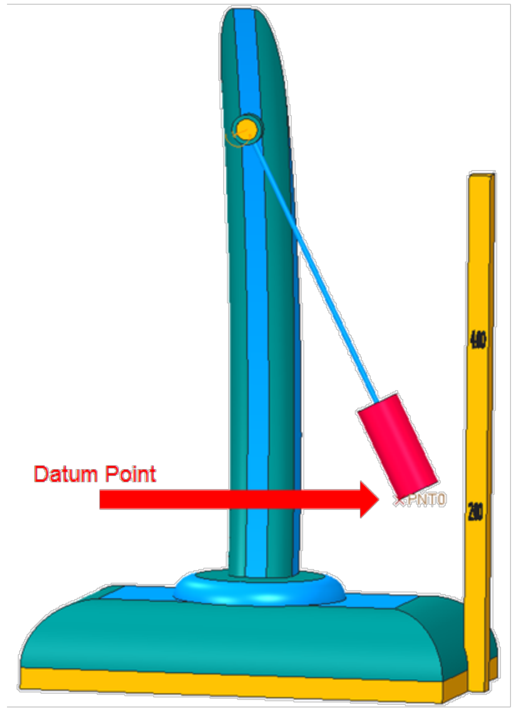
<table>
<tr>
<td>Click on the External Loads tab and Enable Gravity.</td>
<td>
</td>
</tr>
<tr>
<td>Click Run and watch the pendulum swing back and forth.

After it finishes, click OK.</td>
<td></td>
</tr>
<tr>
<td>Define a measure by selecting Measures in the upper menu.</td>
<td>
</td>
</tr>
</table>

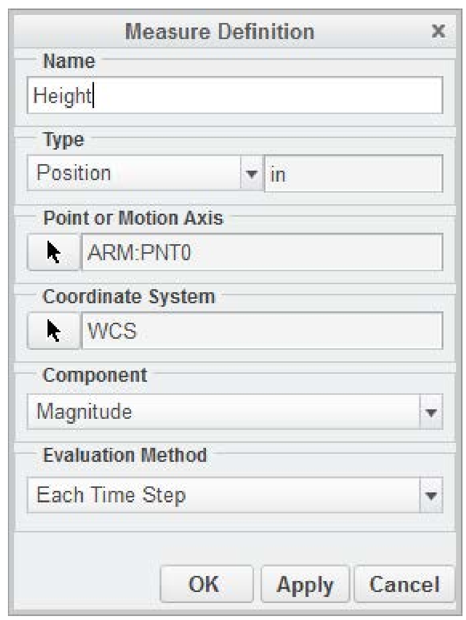
Click on the Result Set **AnalysisDefinition** and then select the **Create new measure** icon, which looks like a sheet of paper.	
Set the datum point display on by clicking on the datum filter icon and then clicking on the **Point Display** to check the box.	

Now left-click on the point at the bottom of the pendulum weight.

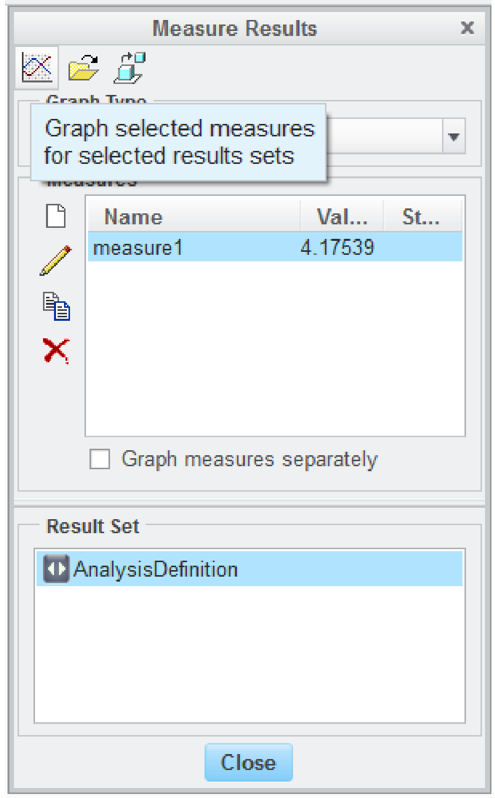
Then click **OK**.



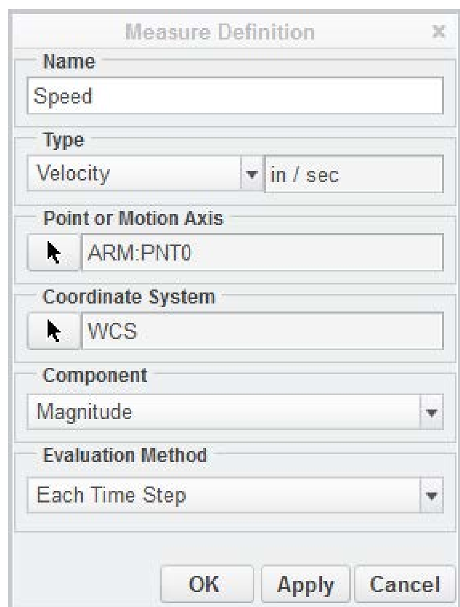
Change the name of this measure to **Height** and click **OK**.

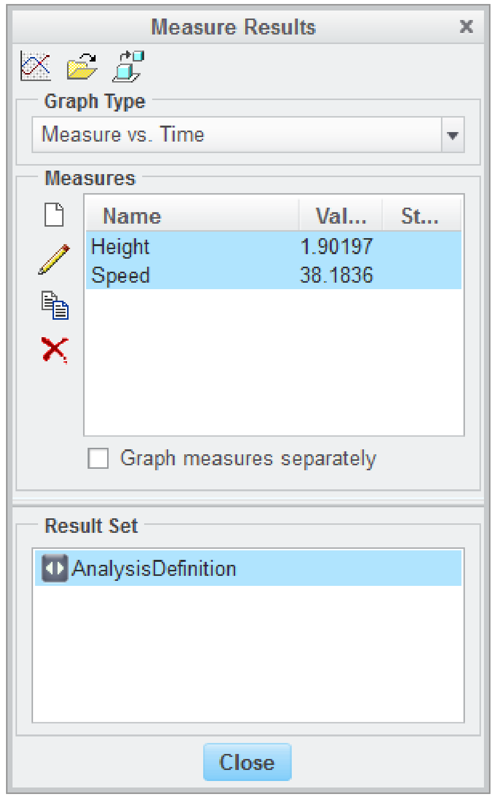


Click on the **Graph** icon at the top of the dialog box to create a graph of the position of the point you selected.

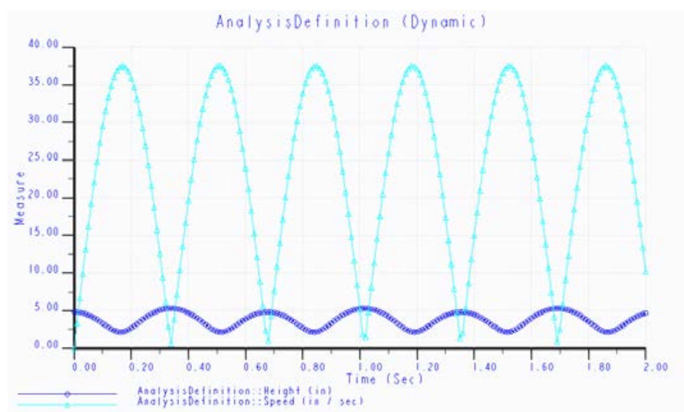


Create a second measure by clicking the **Create Measure** icon and then selecting the same point on the bottom of the pendulum weight. Then change the Type to **Velocity** and change the name to **Speed**.

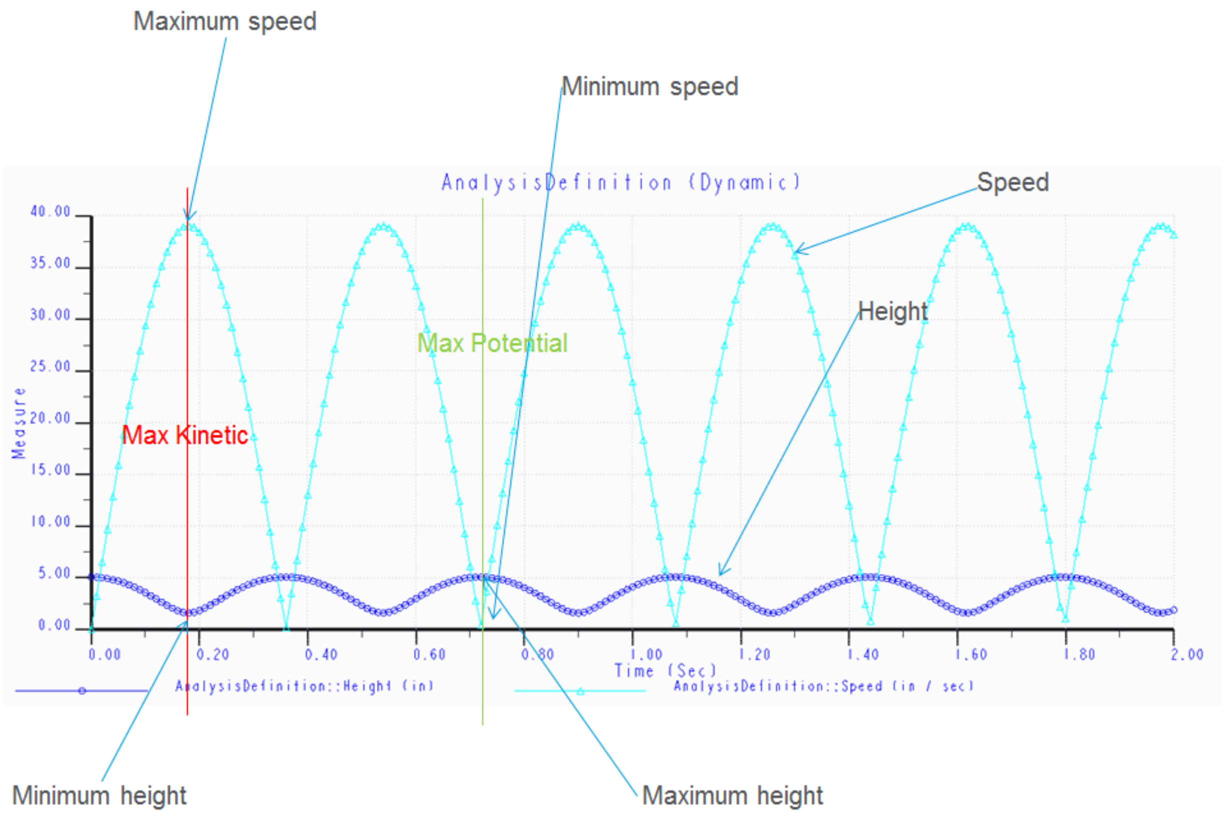


<table>
<tr>
<td>Hold Shift and left-click on the AnalysisDefinition and the Height and Speed measures to select them all. Then click on the Graph icon on the top of the dialog box to graph the measures.</td>
<td>
</td>
</tr>
<tr>
<td>Identify on the graph the points where the height is at a minimum and also when the speed is at a maximum.

Now identify on the graph where the speed is at zero and the height is at a maximum.

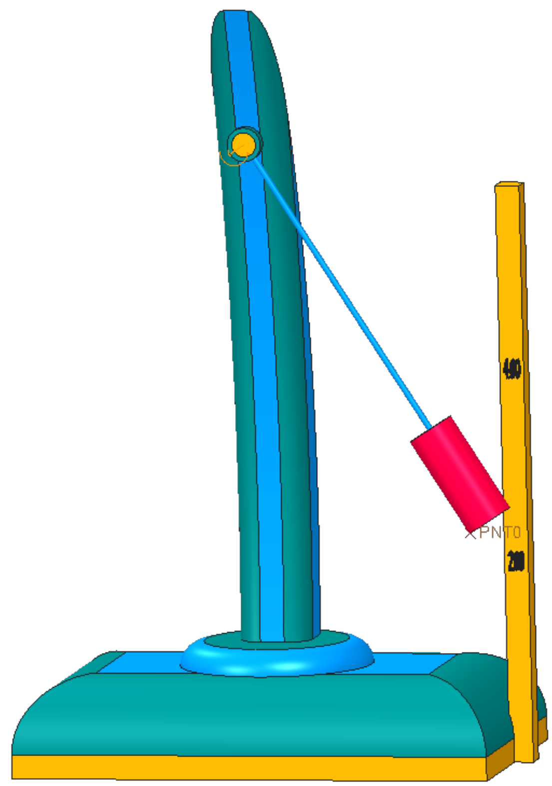
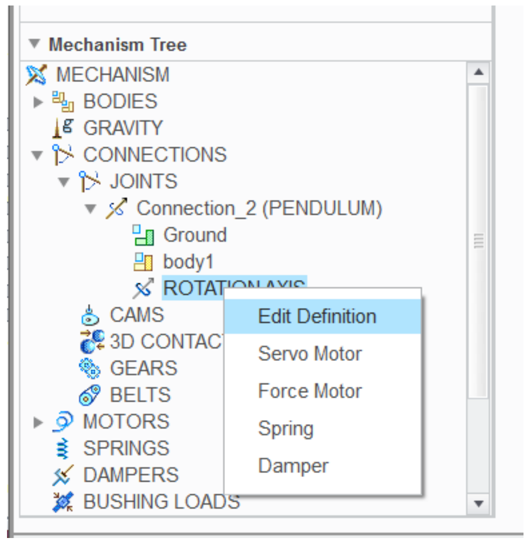
What are these points?</td>
<td>
</td>
</tr>
</table>

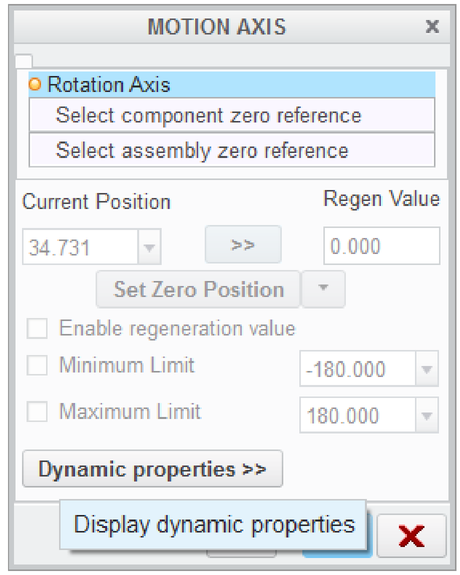
Spend some time analyzing where the maximum kinetic energy points are and where the maximum potential energy points are on the graph. Then identify what those points are in the motion of the pendulum. Identify when kinetic energy is changing into potential energy and when potential energy is changing into kinetic energy.


Maximum speed
Minimum speed
AnalysisDefinition (Dynamic)
Speed
Height
Max Potential
Max Kinetic
Measure
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
Time (Sec)
AnalysisDefinition::Height (in)
AnalysisDefinition::Speed (in / sec)
Minimum height
Maximum height

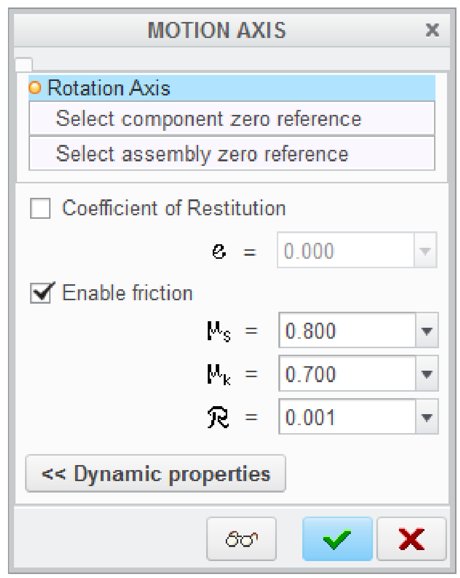
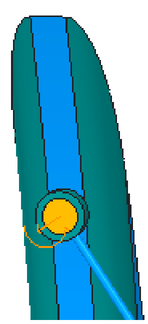
Activity 2: Learn about losses from friction and their impact on the pendulum.

In this activity you will use the pendulum virtual laboratory to explore the effects of friction on a pendulum and how it changes the transfer of energy between potential and kinetic energy.

<table>
<tr><td>Close all of the analysis windows and reset your pendulum to the 2.00 point by holding the CTRL-ALT keys down on the keyboard and left-clicking and dragging the weight up to the 2.00 point on the pole.</td><td>
</td></tr>
<tr><td>Look in the Mechanism Tree and expand the arrow next to the Connections entry. Then expand the Joints and then the Connection_2 (Pendulum). Right-click on the ROTATION AXIS and choose Edit Definition.</td><td>
</td></tr>
</table>

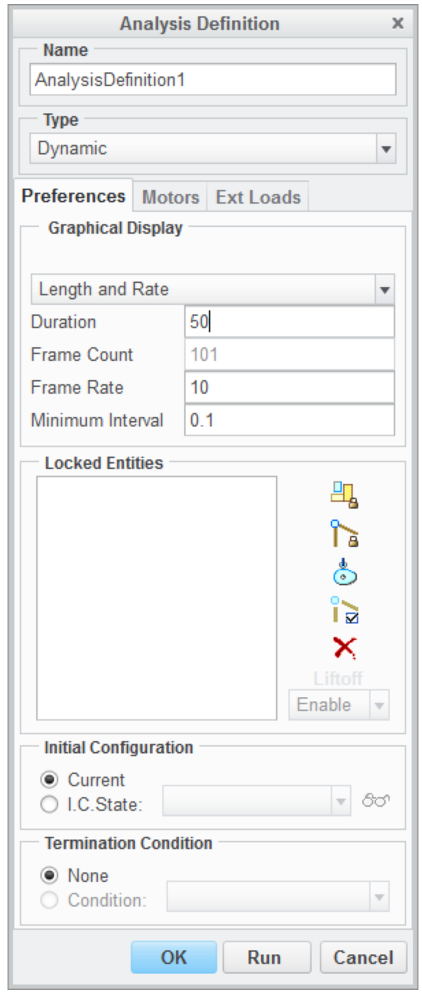
<table>
<tr>
<td>Click on the Dynamic properties button</td>
<td>
</td>
</tr>
<tr>
<td>Enable friction and set the values as shown.

The first value μ_s is the STATIC friction factor. It determines how much friction there is when trying to start something from a static position. The second factor μ_k is the DYNAMIC friction factor or how much friction there is when an object is moving.

Finish by clicking the green check mark.</td>
<td>
</td>
</tr>
<tr>
<td>We have just created friction in the joint at the top of the pendulum. Each time the arm swings, there will be friction that will try to slow down the movement of the pendulum.</td>
<td></td>
</tr>
</table>

Let’s run another experiment by clicking on the **Mechanism Analysis** icon in the upper menu.

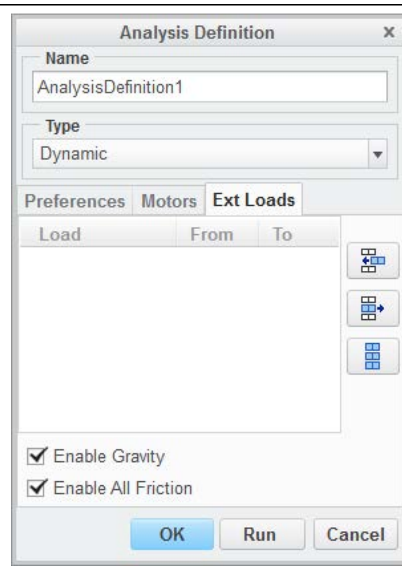
Set the **Type** to **Dynamic** and set the **Duration** to 50.

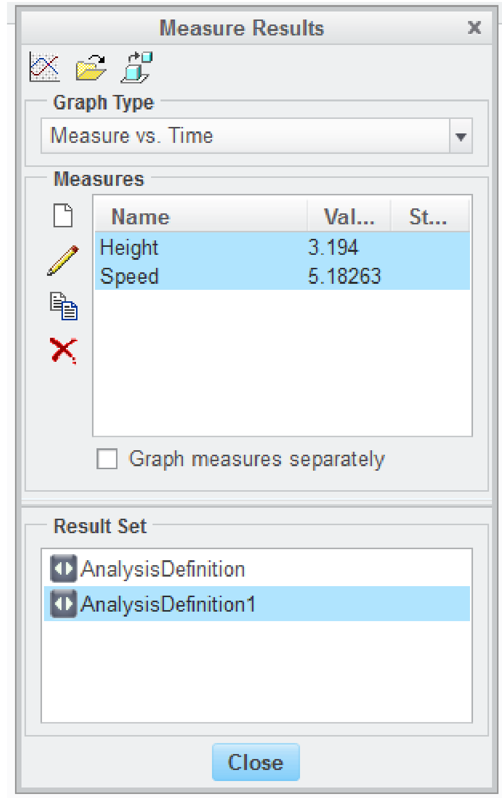


Now click on the **Ext Loads** tab and **Enable Gravity** and **Enable All Friction**, then click **Run**.

Click **OK** once it finishes.

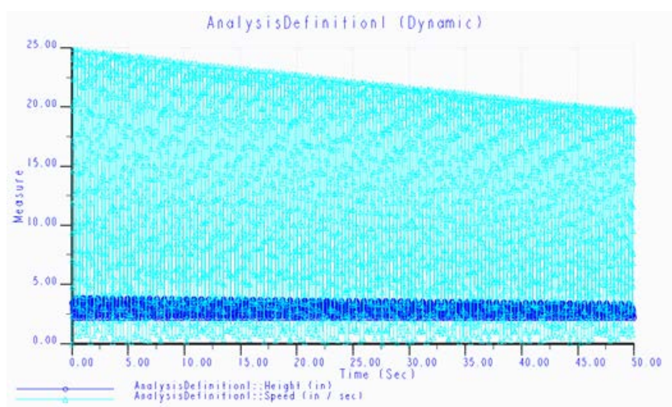
It will take a lot longer this time since we changed the duration to 50 and it must also calculate the friction in every swing of the pendulum.



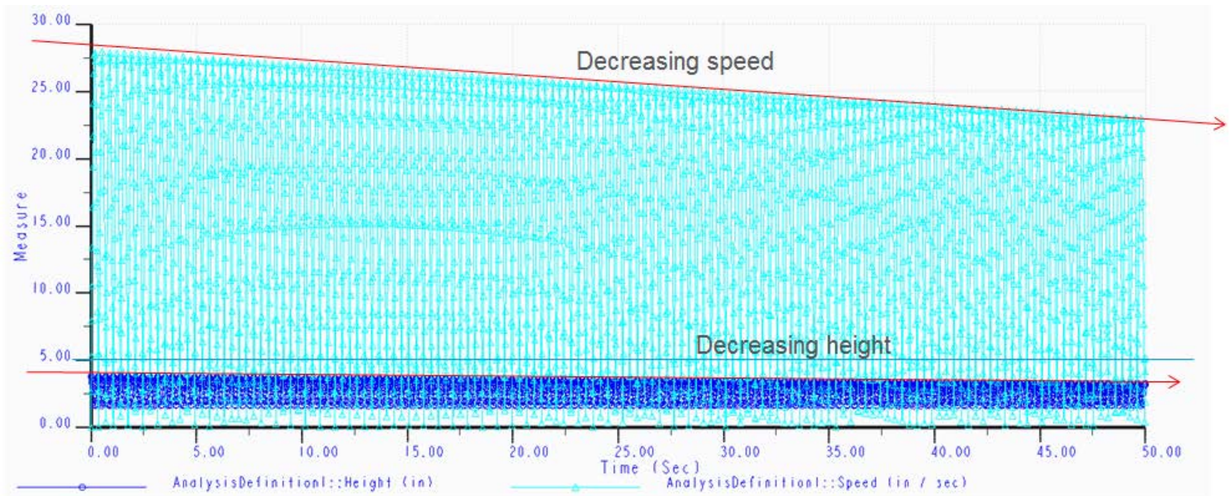
<table>
<tr>
<td>Now click Measures in the upper menu and then select the new AnaylsisDefinition1 and both of the measures we created before and then graph them.</td>
<td>
</td>
</tr>
<tr>
<td>What is happening in this graph?

The velocity is decreasing each time the pendulum swings.

Is the height decreasing as well?

You may have to change the range on the graph to determine the answer.</td>
<td>
</td>
</tr>
</table>

Why is this happening?



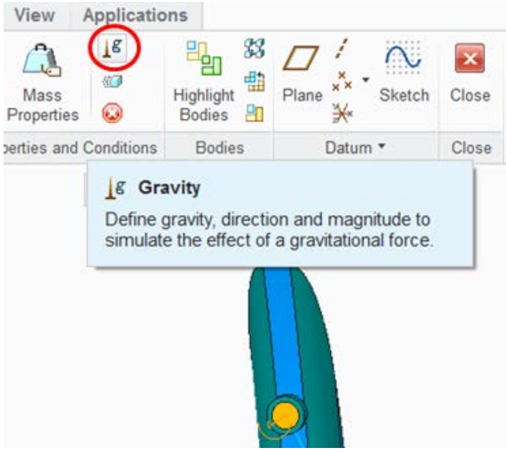
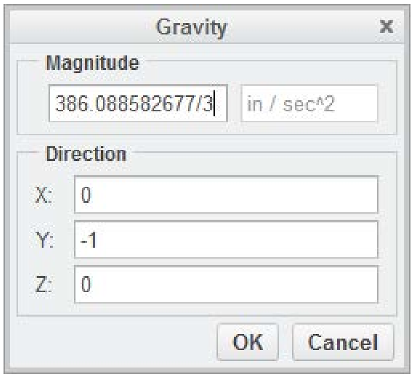
What effect is friction playing on the pendulum?

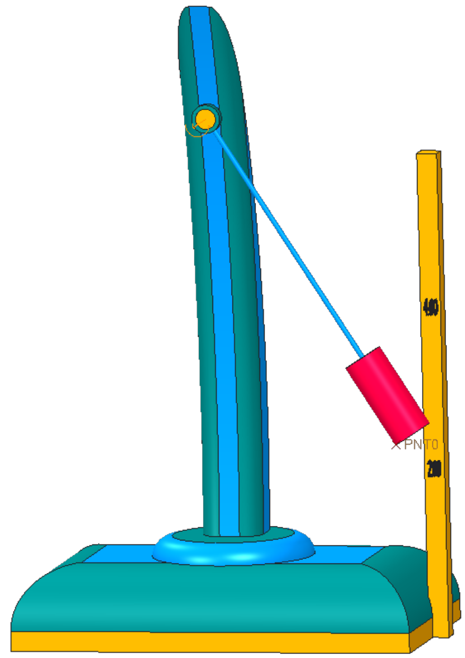
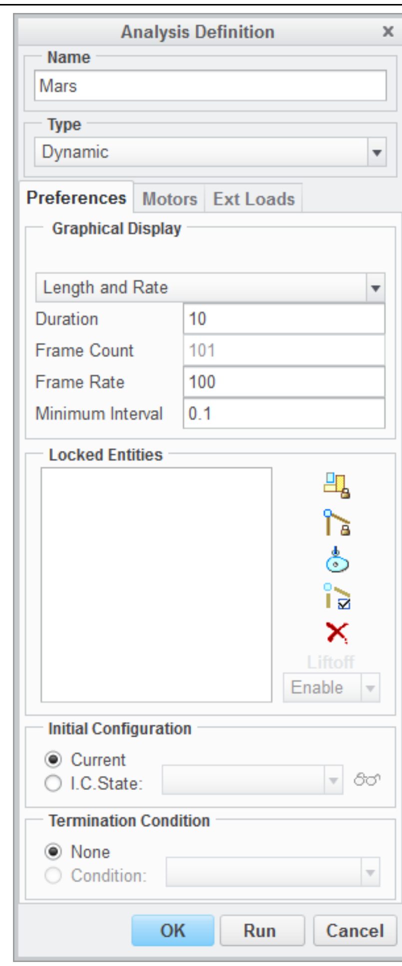
What will happen after a longer period of time?

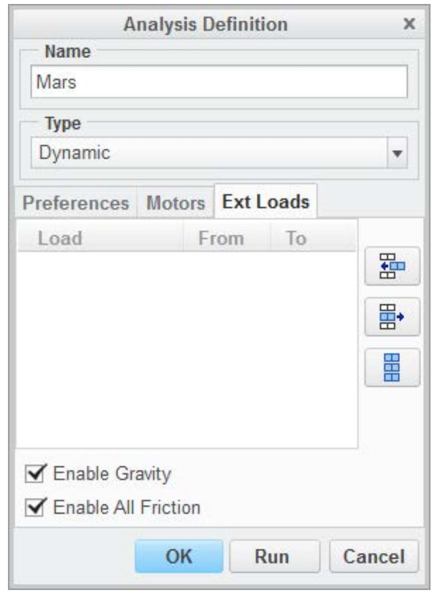
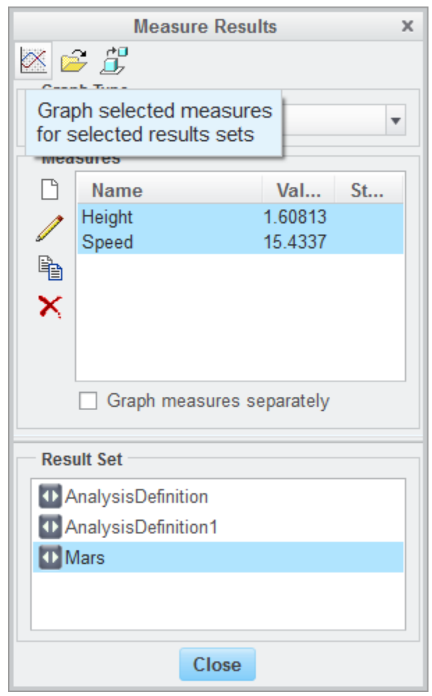
Activity 3: Learn about the impact of changing gravity fields on potential and kinetic energy

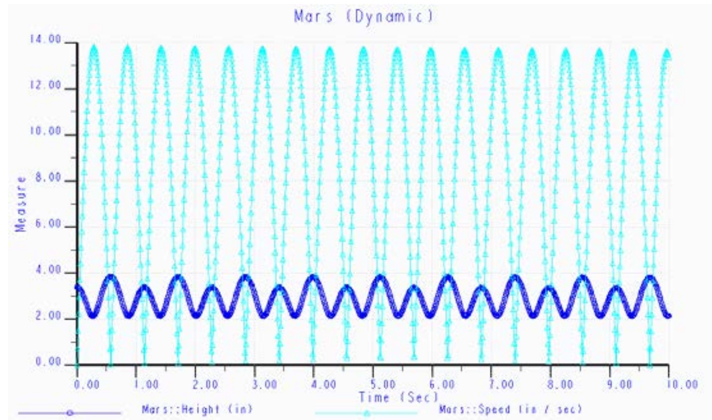
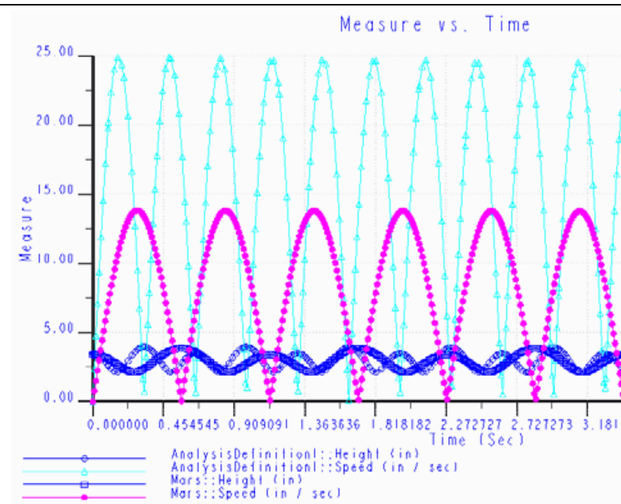
If your swing operates on Mars it will be converting potential and kinetic energy within a different gravitational field. Mars has about 1/3 the mass of Earth and so it has about 1/3 the gravity of Earth.

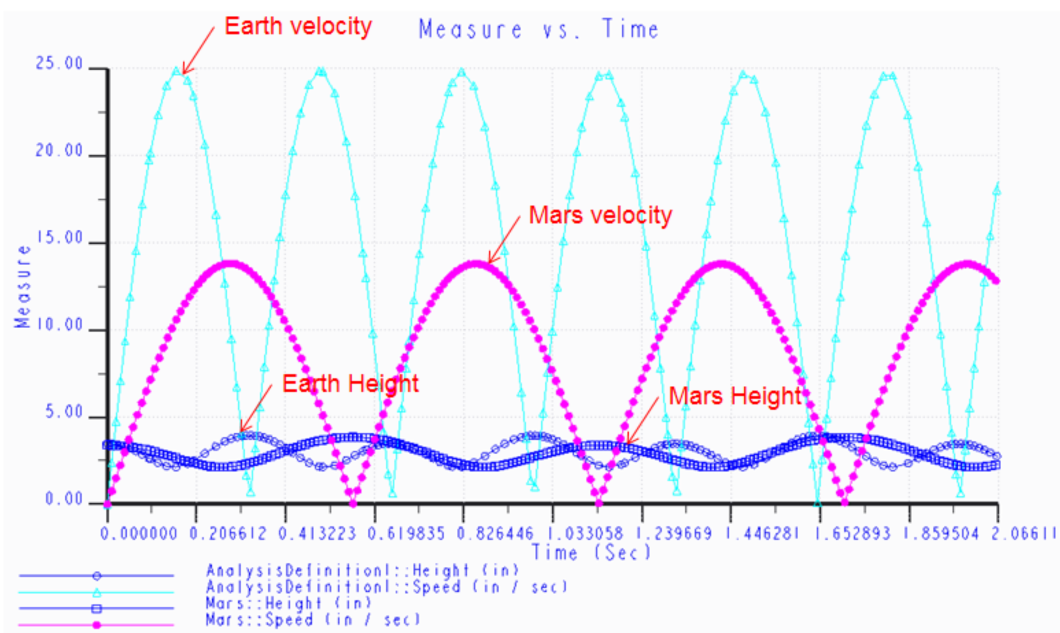
Learn how this different gravitational field will change the potential and kinetic energy of your swing.

Close all of the analysis dialogues and graphs and then click on the **Gravity** icon in the upper menu.	
Set the gravity to 1/3 by typing the divide symbol at the end of the gravity number "/" and then typing "3". Hit enter and then click **OK**.	

Reset your pendulum to the 2 unit position (**CTRL-ALT** left click drag).	
Run a new experiment by clicking on the **Mechanism Analysis** icon in the upper menu. Now change the **Name** to **Mars**, the **Type** to **Dynamic**.	

Click on the **Ext Loads** tab again and **Enable Gravity** and **Enable All Friction**. Now click **Run** and when it finishes click **OK**.	
Graph the results of this experiment by selecting the **Mars** analysis and the two measures and then click the graph tool.	

How is it different from the same plot on earth? How is it the same?	
Hint: Compare the speeds on Earth and on Mars and then compare the heights. Do this by selecting both the Mars analysis and the friction analysis on Earth (AnalysisDefinition1). Then use the zoom tool to zoom into the overlapping region.	



What did you conclude?

Notice that the heights between Mars and Earth are the same but the velocities are very different.

Why is this case?

What can you conclude about the effect of friction on Earth and on Mars?

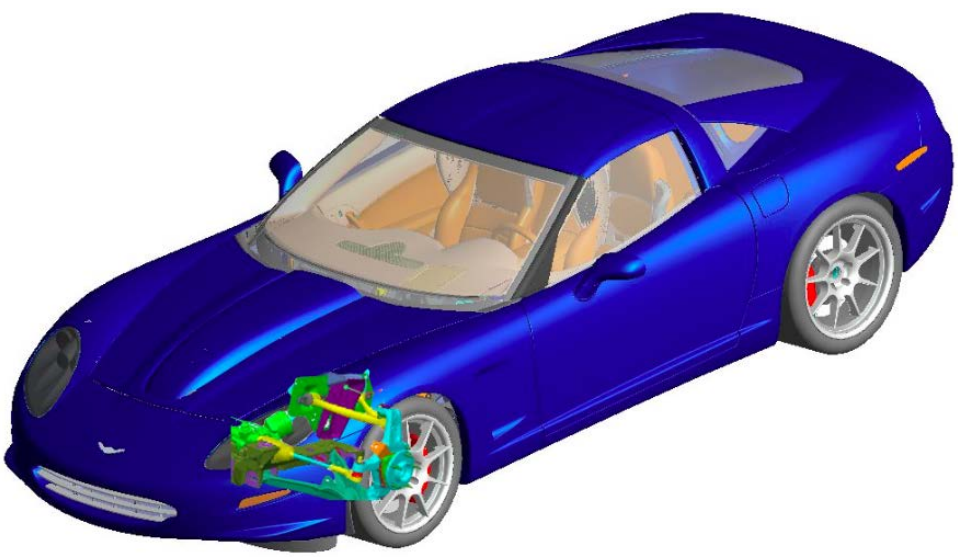
What can you conclude about different gravity fields?

Congratulations, you have finished this exercise!

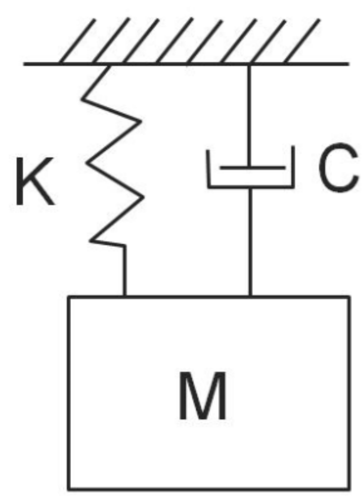
Exercise 12: Mass-Spring-Dashpot Lab

Big Idea: A mass-spring-dashpot model can help in the design of suspensions.

Almost everyone has had the experience of riding in a car with a smooth riding suspension and at the same time almost everyone has had the experience of riding in a truck with a rough riding suspension. In this lab experiment we are going to see how using a mass-spring-dashpot model allows us to develop suspensions for each kind of application.



A mass-spring-dashpot model is comprised of a block of mass connected to s spring and a dashpot so that it can oscillate as shown in the figure. The M represents the magnitude of the mass. The K represents the stiffness of the spring and the C represents the viscosity of the dashpot. The reason a mass-spring-dashpot model works well in representing a suspension is that a car's suspension can be simplified into these three components connected in this way.



We are going to use another PTC tool called "Mathcad" to document this lab. The reason for using Mathcad is that it allows for “live” mathematics in the document. So while we show all of the pages here in this exercise, there is an accompanying Mathcad worksheet that looks exactly the same but is set up so that values can be changed and the equations will all update. So the Mathcad worksheet can be used in conjunction with the Creo model to help design suspensions.

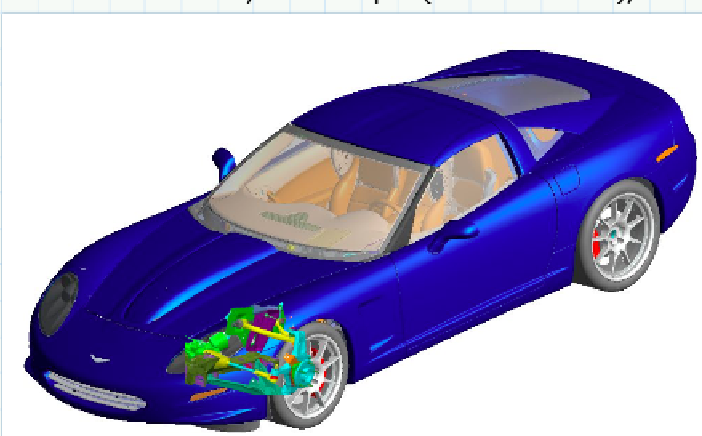
Activity 1: Explore the Mathcad Worksheet.

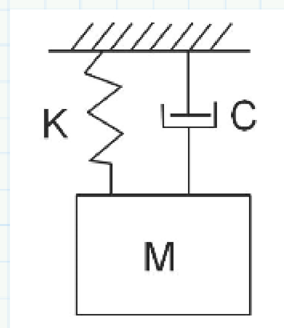
Homework set #1:

Designing your own automobile suspension

Objectives: *1. To learn how to use ordinary differential equations to predict an automobile's suspension and to design the suspension for a specified performance.*
2. To bridge the gap between mathematics and real applications

Description:
The suspension of a car can be modeled as a simple mass-spring-dashpot system. Assuming that the mass of the car can be lumped into a single mass and the springs and shock absorbers can be lumped as well into single units, the whole system can be simplified into a system with one mass, one dashpot (shock absorber), and one spring as shown.

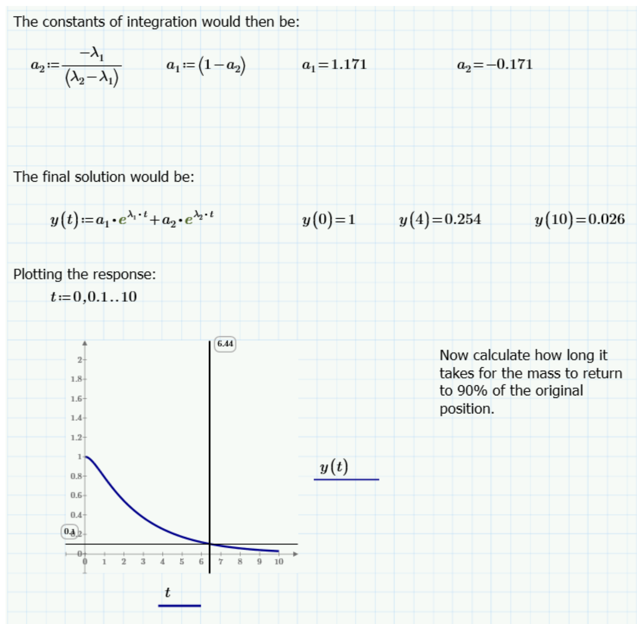
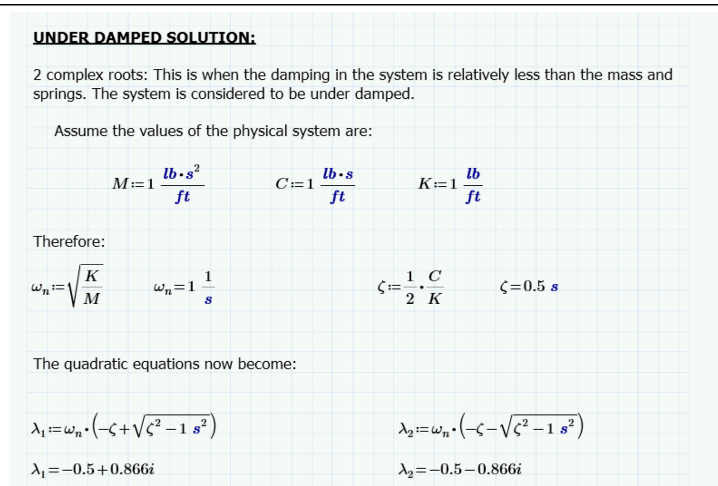


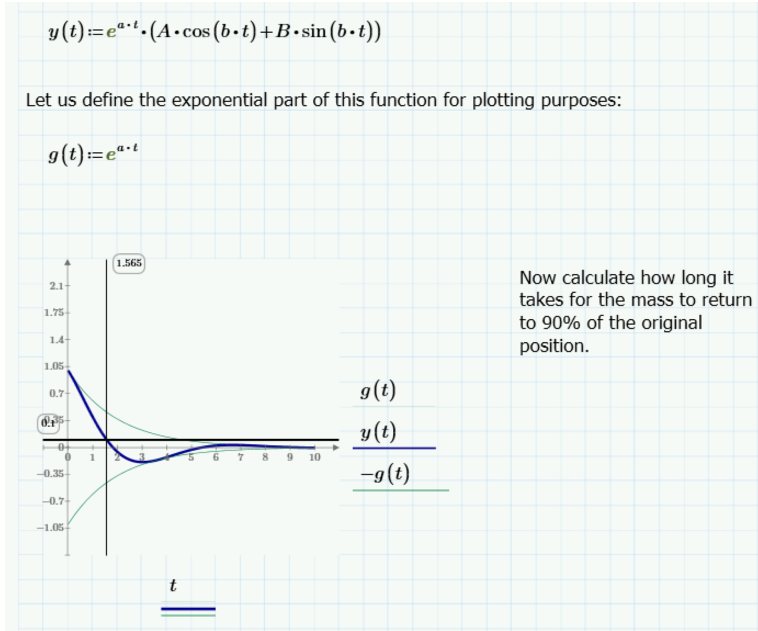
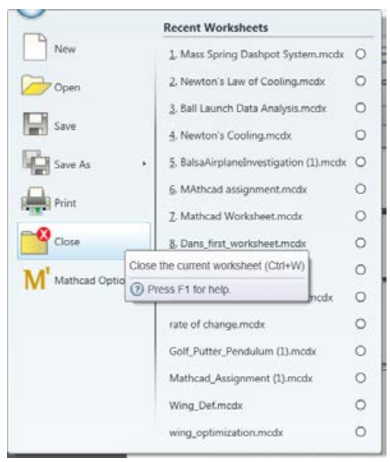
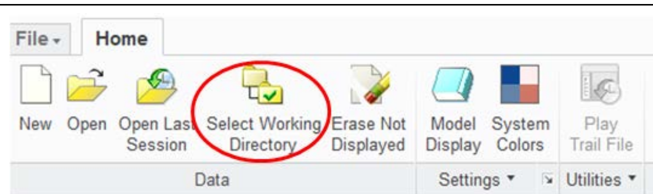


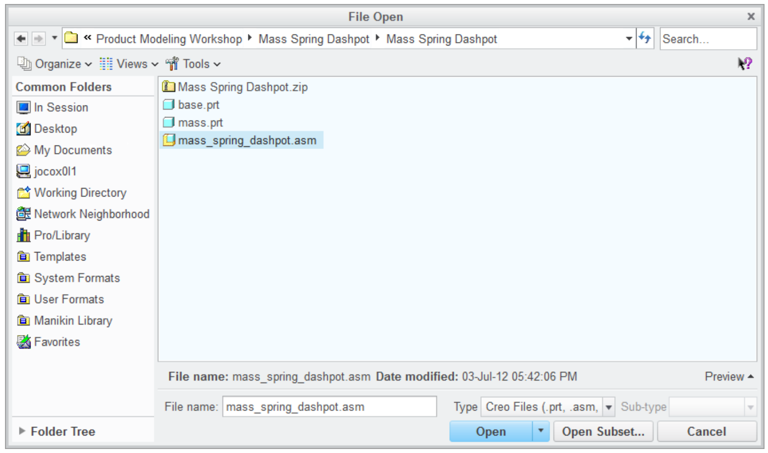
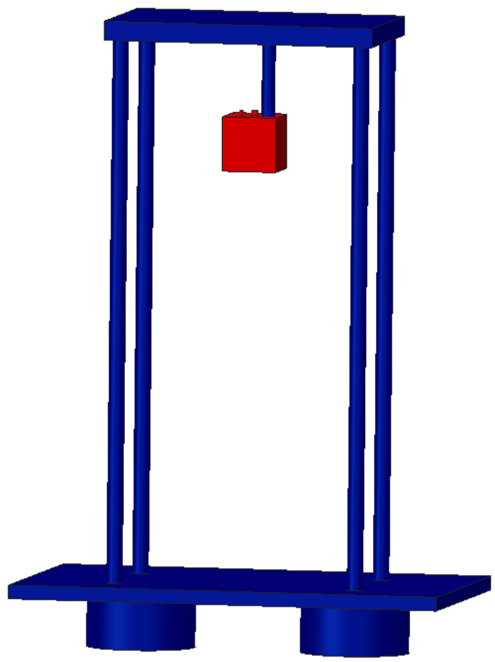
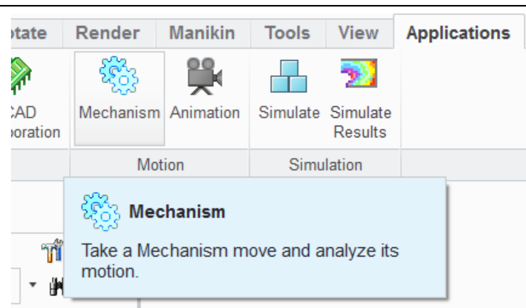
Where: M = Mass of the car, C = viscous damping in the suspension, and K = the springs in the suspension system. Doing a sum of forces produces the following equation:

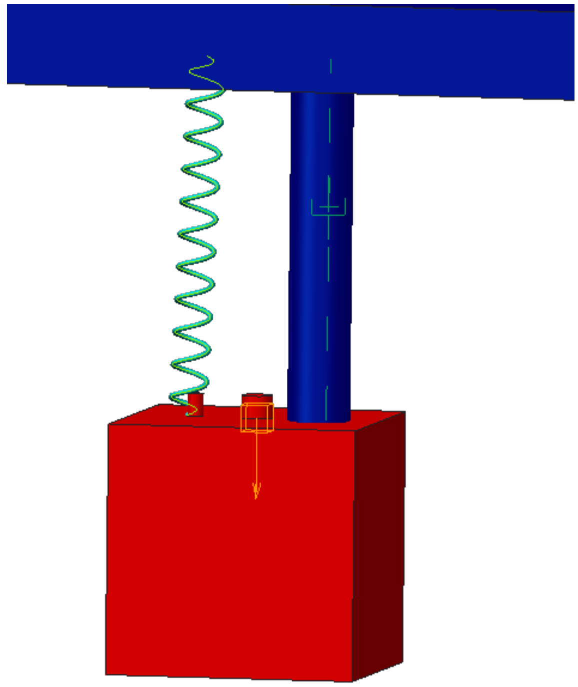
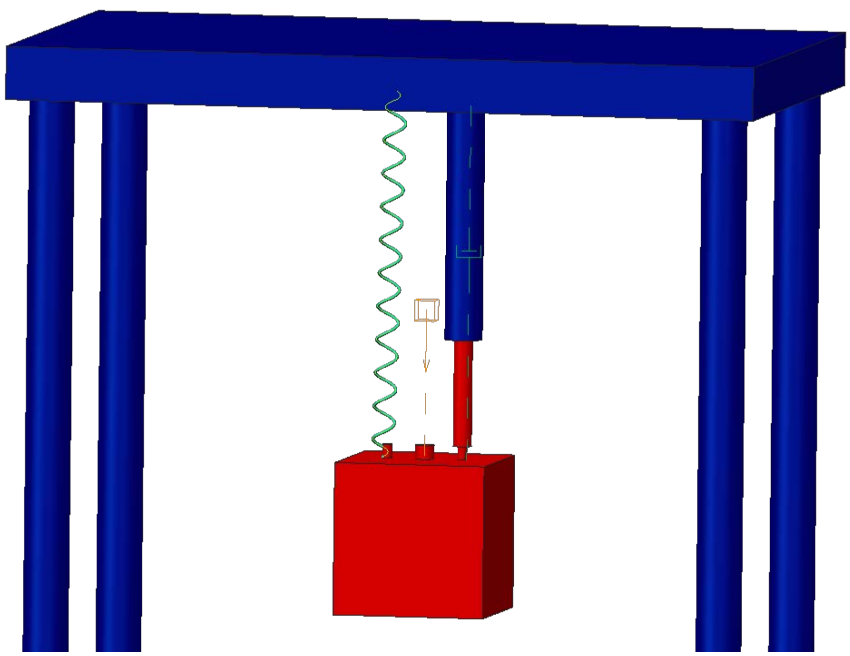
$$\sum F = 0 = M \cdot \frac{d^2}{dt^2} y(t) + C \cdot \frac{d}{dt} y(t) + K \cdot y(t)$$

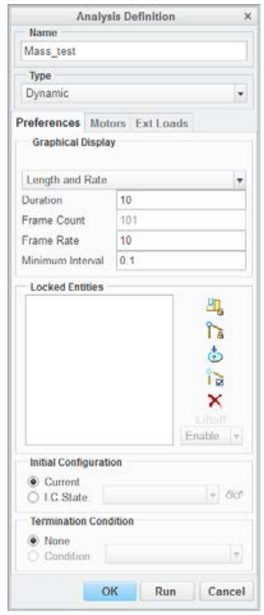
EXPLORING THE MATHCAD WORKSHEET

Step 1: Begin by opening **the** Mathcad Worksheet by double clicking on "**Mass Spring Dashpot System.mcdx**" in the folder **Mass Spring Dashpot**	
Step 2: Read through the worksheet. Don't worry about whether you understand differential equations. Just examine how the entire homework set is set up in Mathcad.	
Step 3: Notice how units can be assigned to numbers and Mathcad actually converts and manages the units automatically.	

Step 4: Also notice that graphs can be used to help illustrate principles. All of these graphs are live so that if values are changed the graphs update.	
Step 5: The purpose of this exercise is to expose you to what Mathcad can be used for but not to teach you how to use Mathcad. So now let's close Mathcad and move to the Creo Model of the mass-spring-dashpot.	
Start Creo and then set your working directory to the Mass_spring_dashpot folder.	

Now open the file called: "**Mass_spring_dashpot.asm**"	
Turn off the datums so that your model is uncluttered.	
Now click on the **Applications** tab in the upper menu and then choose **Mechanism**.	

Notice that a spring and dashpot show up in the mechanism. These are elements of this experiment that have been added within the Mechanism application.	
Now press **CTRL-ALT** and left click to move the mass up and down to explore the range of motion in this model. Move the mass down below the blue rod. This will be our starting point.	

<table>
<tr>
<td>Click on Mechanism Analysis in the upper menu and name this “mass_test”. The change the Type to Dynamic.</td>
<td>
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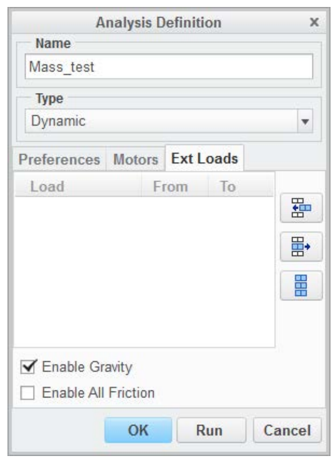
<td>Then click on the Ext Loads tab and Enable Gravity.

The click Run.</td>
<td>
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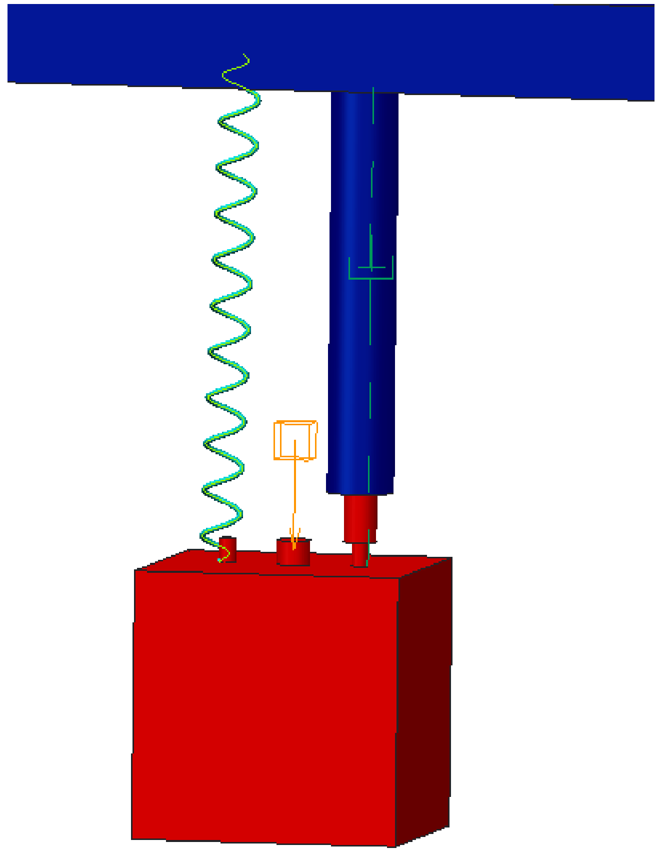
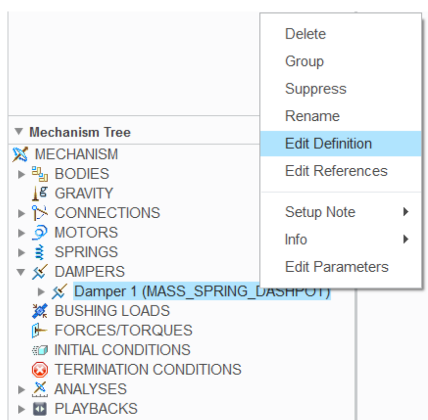
<tr>
<td>The motion of the mass is that of an under-damped system, meaning that the spring dominates the response and therefore there are some oscillations.

This is the best type of system for suspensions because it responds quickly but the oscillations die out quickly as well.</td>
<td></td>
</tr>
<tr>
<td>Now let’s change the dashpot value so that the dashpot dominates the response.

Go to the Mechanism Tree and expand the Dampers entry and then right click on the Damper 1 entry and select Edit Definition.</td>
<td>
</td>
</tr>
<tr>
<td>Change the C value to .1 lbf sec/ft and hit Enter, then click the green check mark to finish.</td>
<td>
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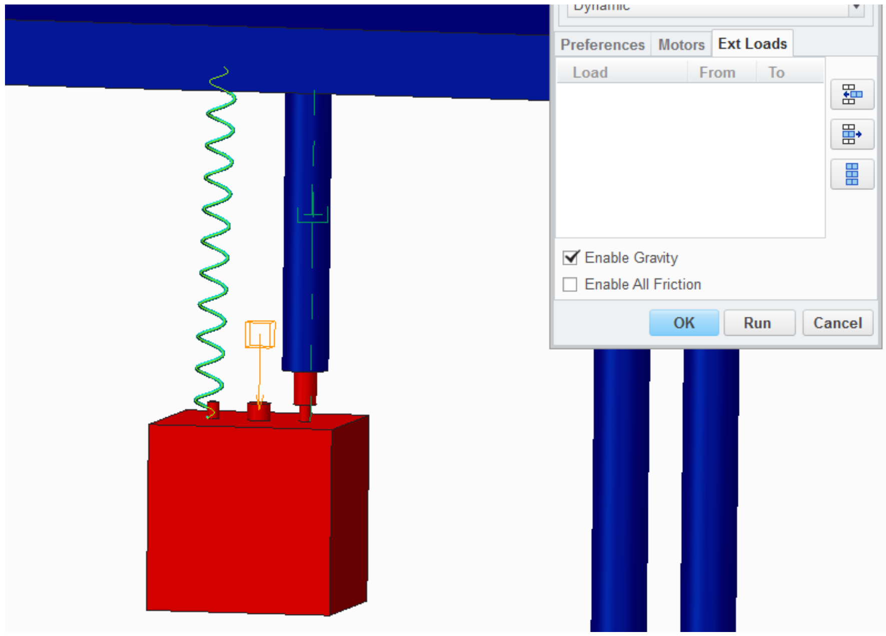
Run the analysis again and notice that there are no oscillations. This means that the system is overdamped. This is not a good system for a suspension since it can't respond quickly enough to changes in the road. Balancing the dashpot value with the stiffness of the spring and the weight of the mass is an important part of designing an effective suspension.	
Now close Creo	
CONGRATULATIONS YOU HAVE COMPLETED THIS EXERCISE	