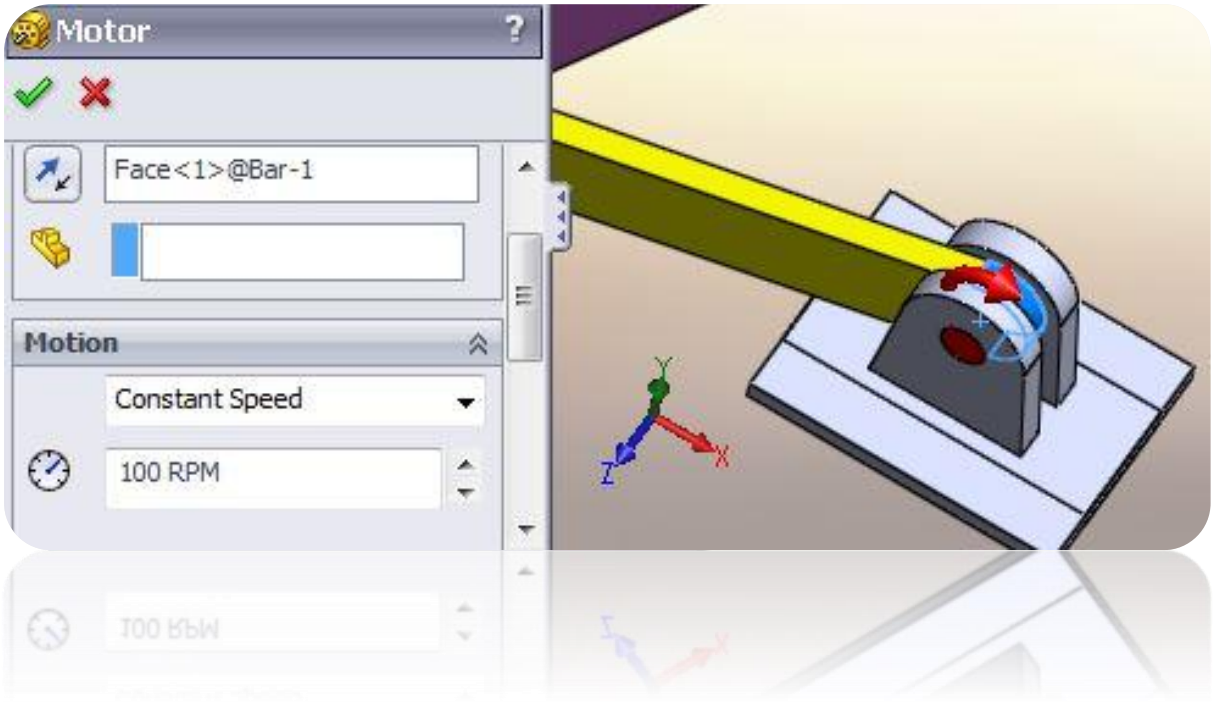
SolidWorks Motion Study Tutorial



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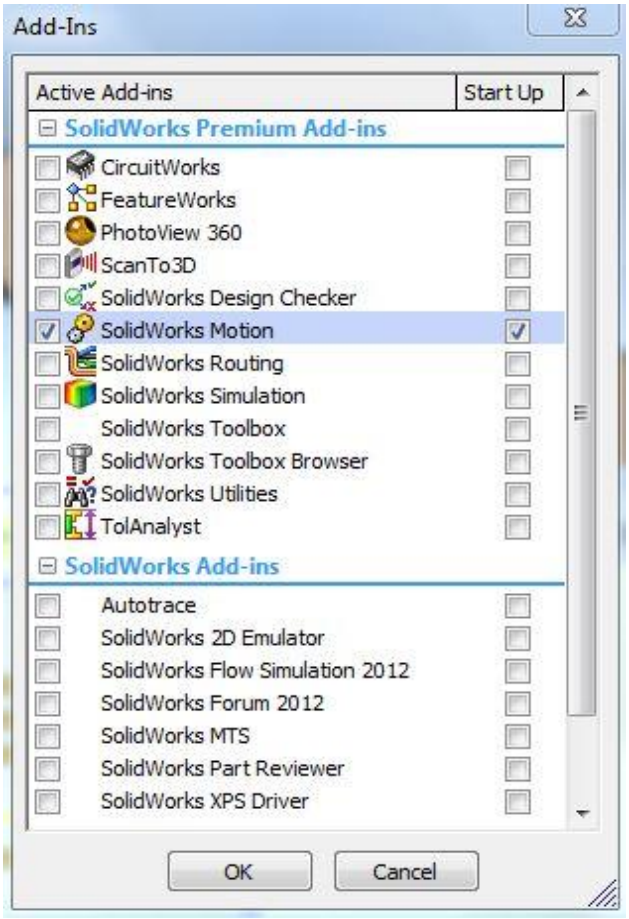
August 2013

Getting Started

This tutorial is for you to understand the basics of SolidWorks Motion Analysis and use it to simulate and get the results for problems.

SolidWorks Motion Analysis allows you to study two major types of problems relating to the motion of solid bodies.

1. Kinematics: Study of the motion of a rigid body without considering the forces that result in the motion of the body.
2. Dynamics: Study of the motion of a rigid body as a result of the applied external forces on the body.



SolidWorks Motion Analysis allows you to answer the following questions:

1. Will the assembled components of your design move as you intended?

2. Will the assembled components of your design collide when it's in motion?

4. What are the magnitudes of the forces between two parts in contact with one another?

5. What is the path of the solid body?

6. What is the velocity, acceleration, angle, or reaction force at an instant?

In order to do motion analysis you need to add motion analysis plugin to your assembly file.

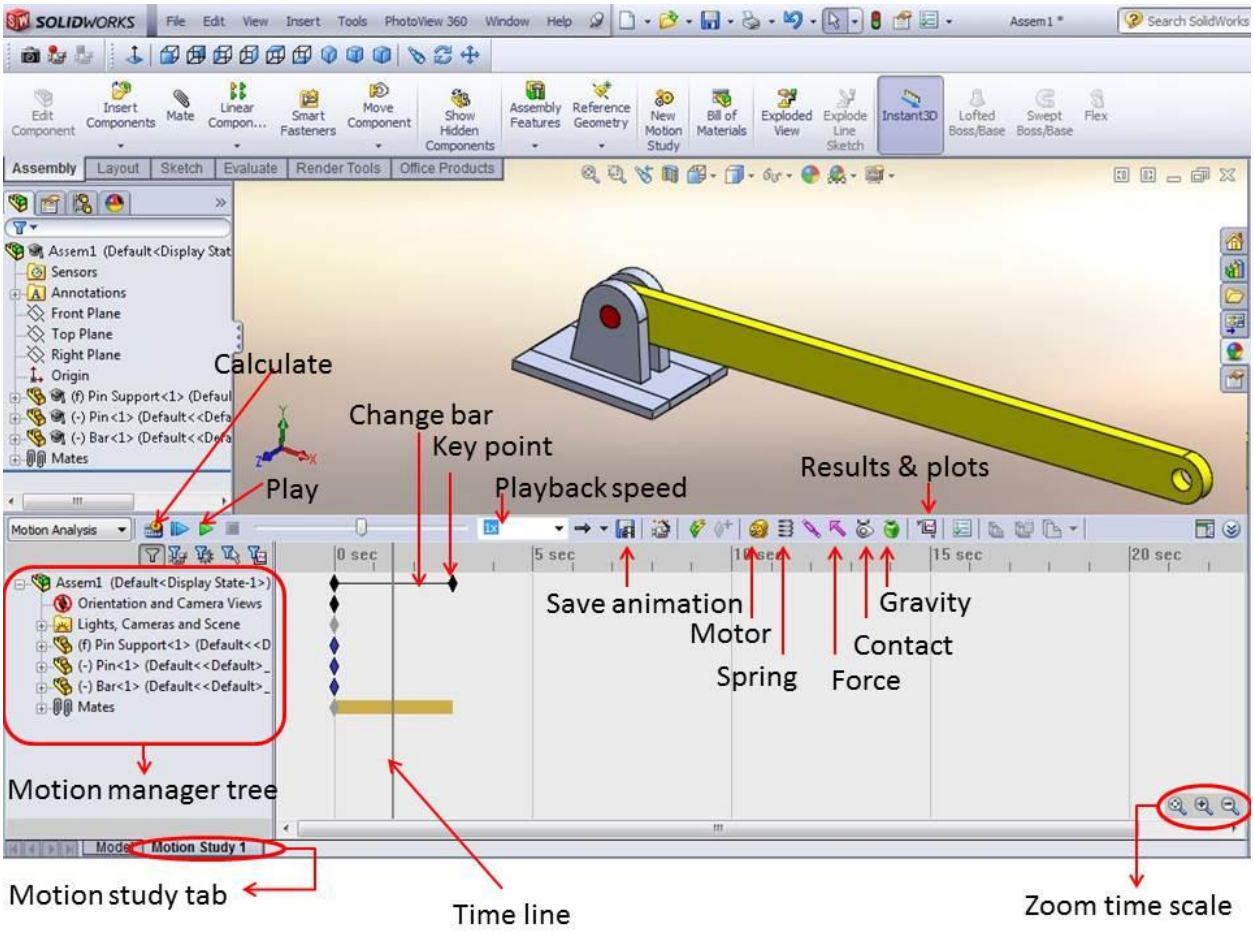
Tools → Add-Ins →Select SolidWorks Motion.

Note: Most of the details in this page are extracted from 'SolidWorks Motion,' 21 July 2011, by Professor Erik Spjut, Engineering Clinic Director, HMC.

http://www.hmc.edu/files/engineering/clinic/Solidworks_motion_final.pdf

Introduction to Motion Analysis

Motion Analysis can be found only in assembly files. It has several features related to the motion of an assembly file. Figure below shows a screen shot of a simple pin connection assembly file.



Features of Motion Study

- **Motion Study Tab** – This tab allows us to analyze the motion study of the assembly file.
- **Motion Manager Tree** – This contains all the parts, sub-assemblies, mates, and the simulation elements.
- **Calculate** – This button allows calculating the motions of the assembly and helps to update after changes made.
- **Play** – This button allows us to play the animation to see how it works after calculating the motion.
- **Playback Speed** – This helps to reduce or increase the speed of the animation.
- **Save Animation** – This button helps to save the animation as a video.

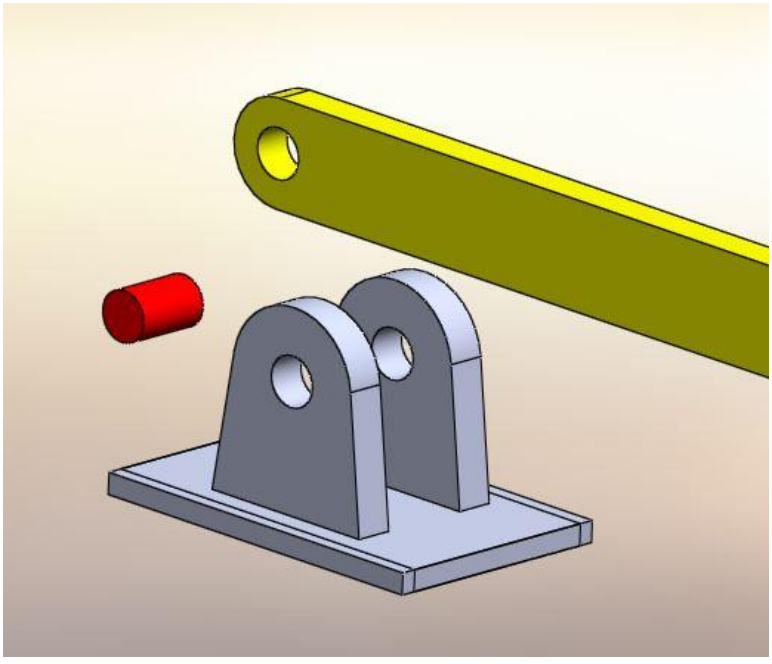
- **Motor** – This allows simulating a motor or giving a torque to the animation such as at pin connections.
- **Spring** – This allows simulating a spring in motion where you can edit the spring constant and length.
- **Force** – This allows simulating forces on any part of an object.
- **Contact** – This allows stopping the interference between solid objects and adjusting the friction between objects when it is in motion.
- **Gravity** – This allows simulating the effect of gravity on solid objects.
- **Results & Plots** – This allows getting the results and plots for displacement, velocity, force, angles, etc.
- **Zoom Time Scale** – This allows zooming in/out the timeline.
- **Key Point** – This point decides where the motion has to be stopped.
- **Time line** – This shows the moving time frame.

Introduction to Mates

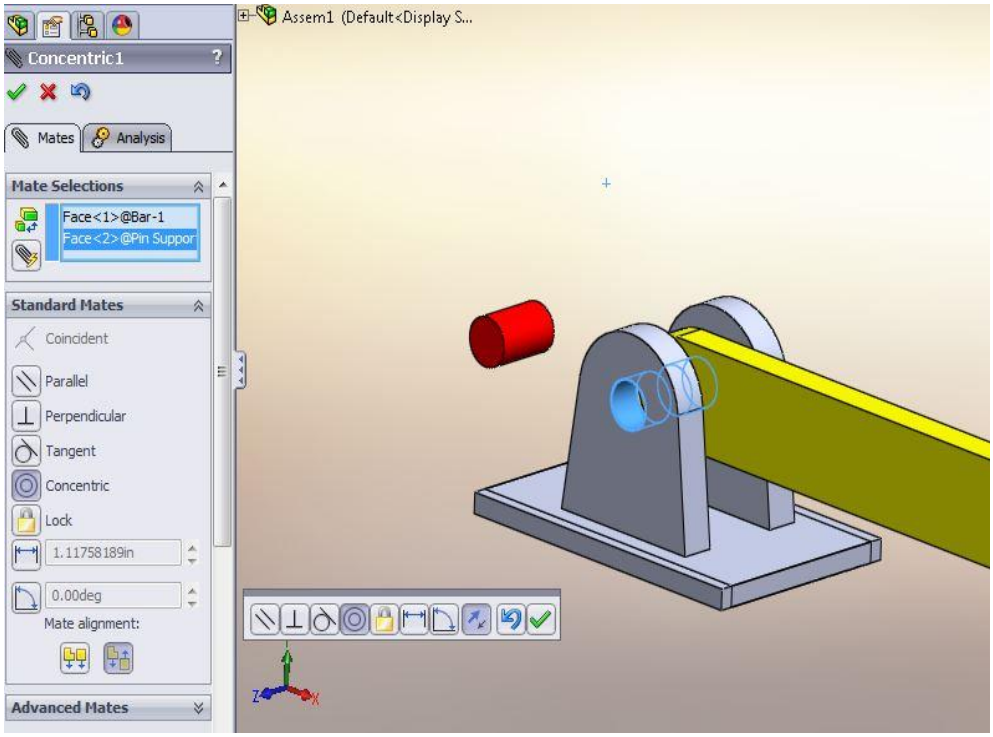
Mates are crucial for motion analysis. There are some typical mates such as coincident, concentric, parallel, tangent, and so on that we use to assemble and put the parts together. This section should be a review of material covered in ME-110.

The following screen shots of an assembly file shows some of the typical mates.

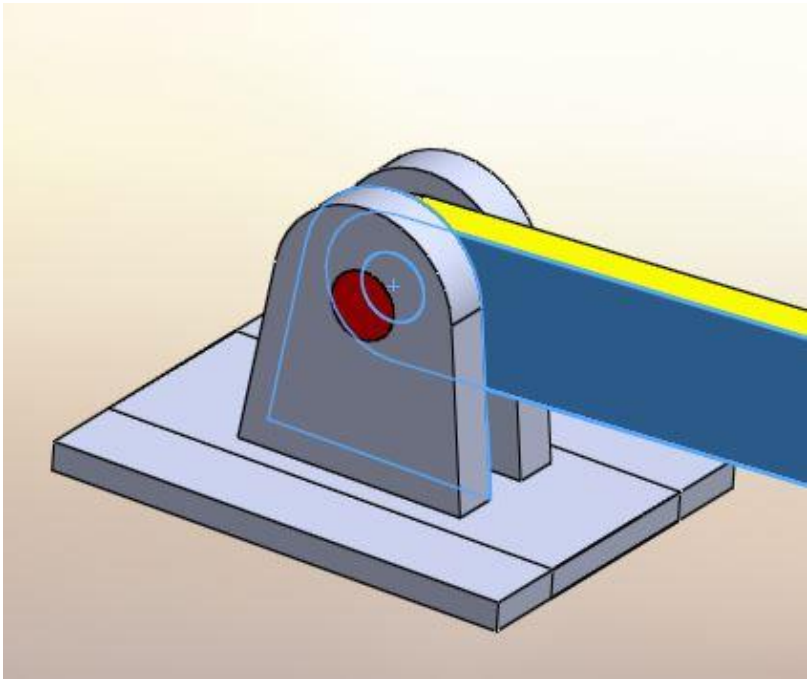
1. Before mates are applied to the assembly



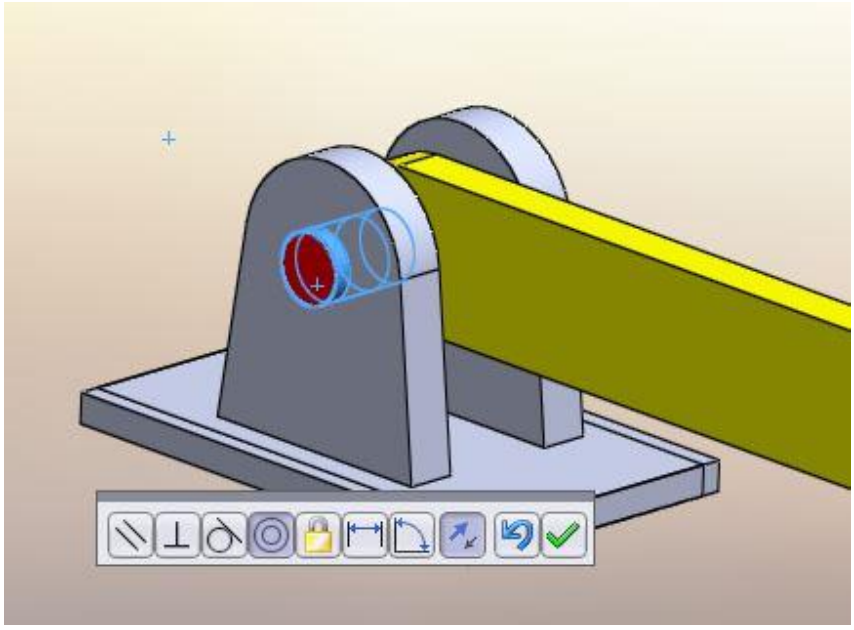
2. Select the cylindrical face of the bar and pin holder and it will mate it to concentric by default.



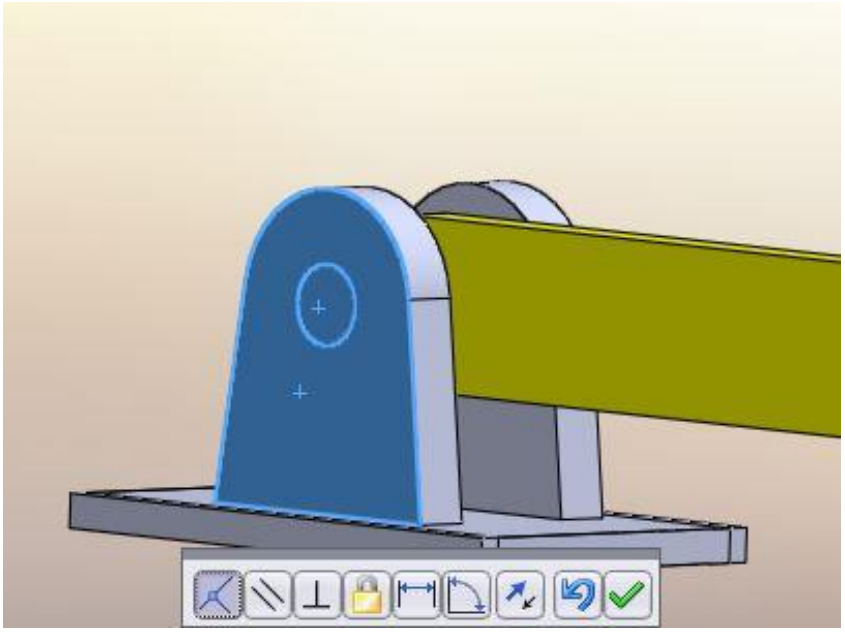
3. Select the face of the rod and the inner face of the pin holder (Right click on the surface of the pin holder and then click select other to select the inner face) and it will mate it to coincident by default.



4. Select the cylindrical face of the pin and pin holder and it will mate it to concentric by default.



5. Select the circular face of the pin and the face the pin holder as shown in the figure which will select the coincident mate by default.

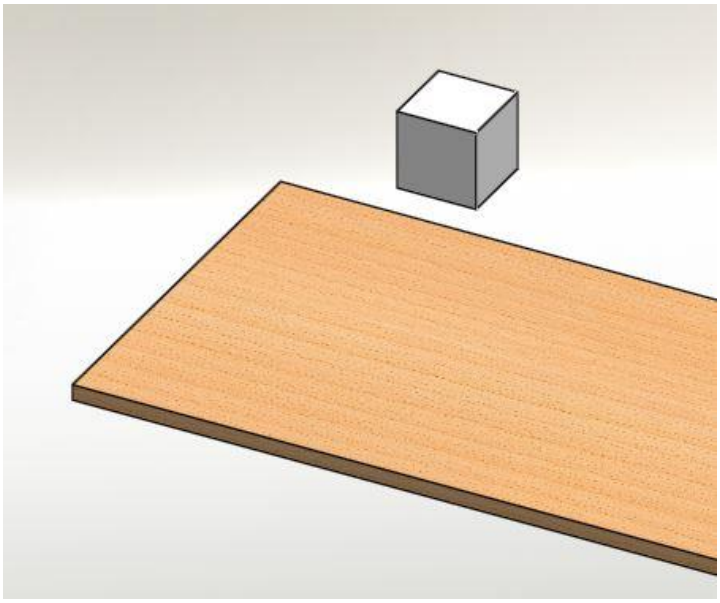


The above example gives a demonstration of basic assembly and mates. You can download the part and assembly files from the website under class materials. Create a new assembly file and practice to understand it well.

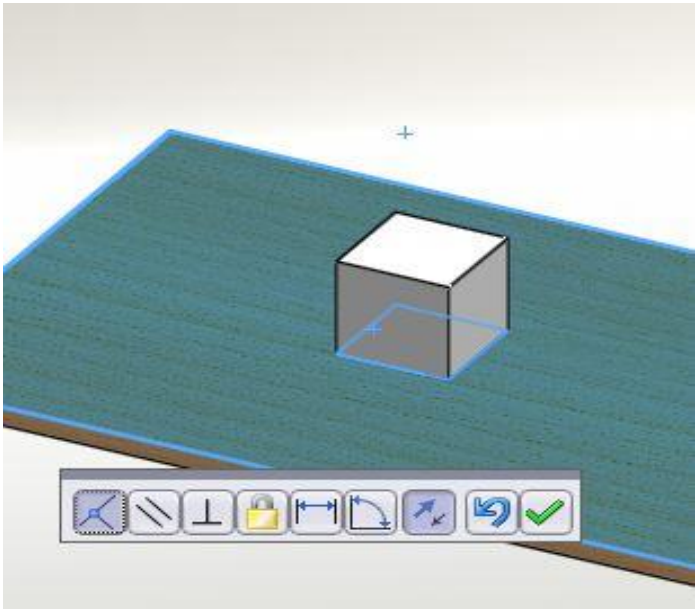
Lesson 1

This lesson will help you to get familiar with forces acting on a body. You can download the part and assembly files from the website under class materials.

- Open the assembly file.



- Click the mate option in assembly features → Select the top surface of the floor and the bottom surface of the cube which will go for the mate coincident by default → Click the check mark to add another mate.

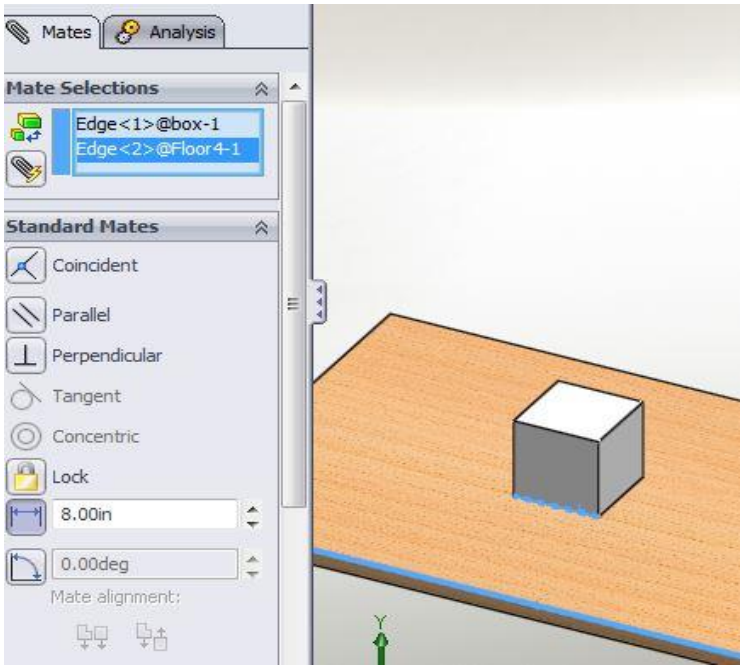


- Dealing with friction and mates

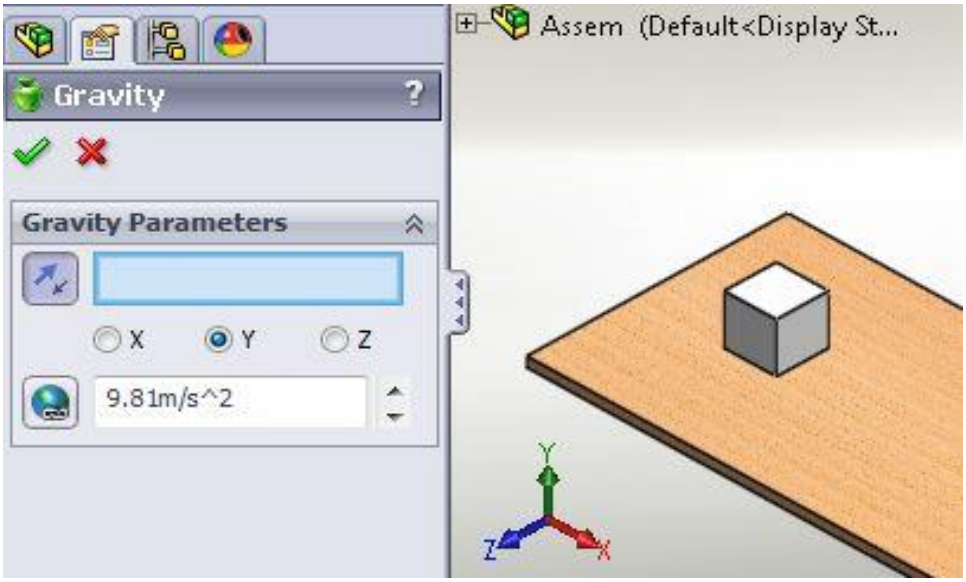
  Note: The typical way to attach an object to the floor or to another object is by adding a coincident mate in between those two faces so they will be touching together at the selected surfaces. This would change if we need to add friction into our motion analysis.

  When you need to add friction, first **replace the coincident mate with a parallel mate** without changing anything else. Then add friction via Solid Body Contact.

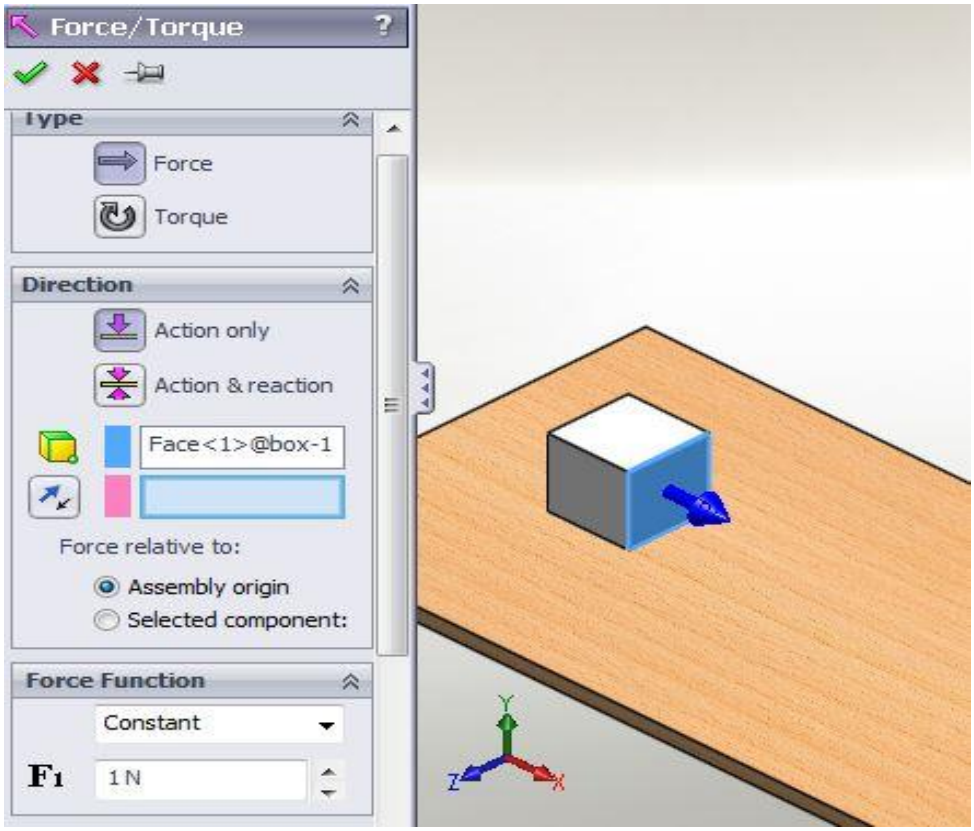
- Click the side edge of the cube and the edge of the floor as shown below → It would select the concentric mate by default, but go and select the distance mate as shown and specify a distance between those two line. This mate causes the box move along a straight path.



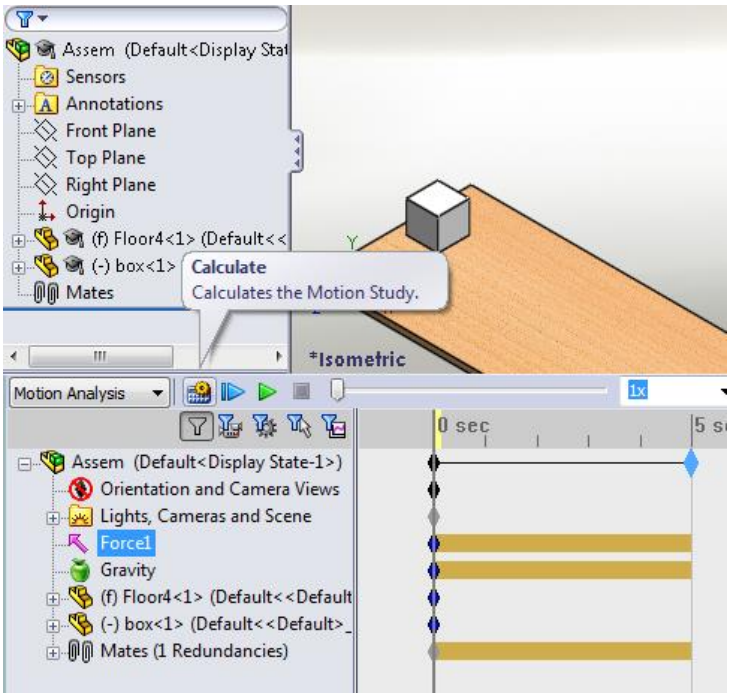
- To change the mass properties go to tools → Mass properties. You can change the mass (make it 5 kg) and the location of center of mass.
- Gravity needs to be added in order to simulate the effect of weight. Choose the direction of gravity as you want it to be.



- Add force to the object. You can choose the face where the force is acting and then can change the direction as shown below. Then you can change the magnitude of the force (make it 10 N).



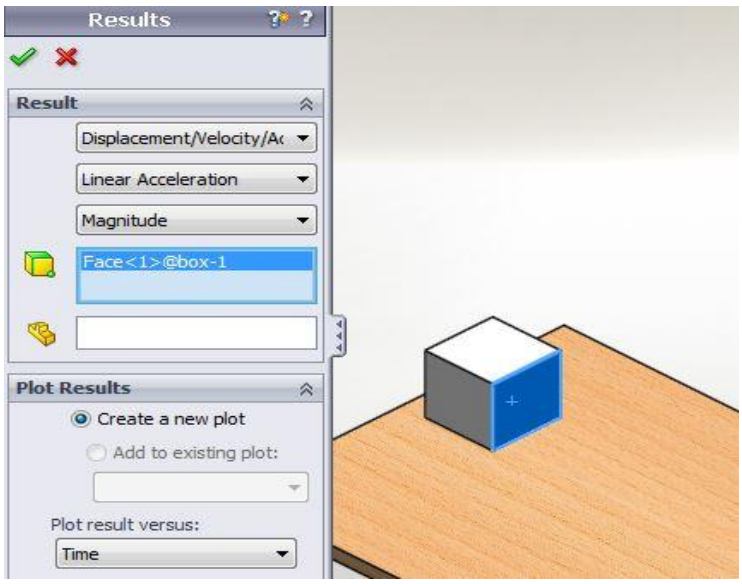
- Calculate the motion.



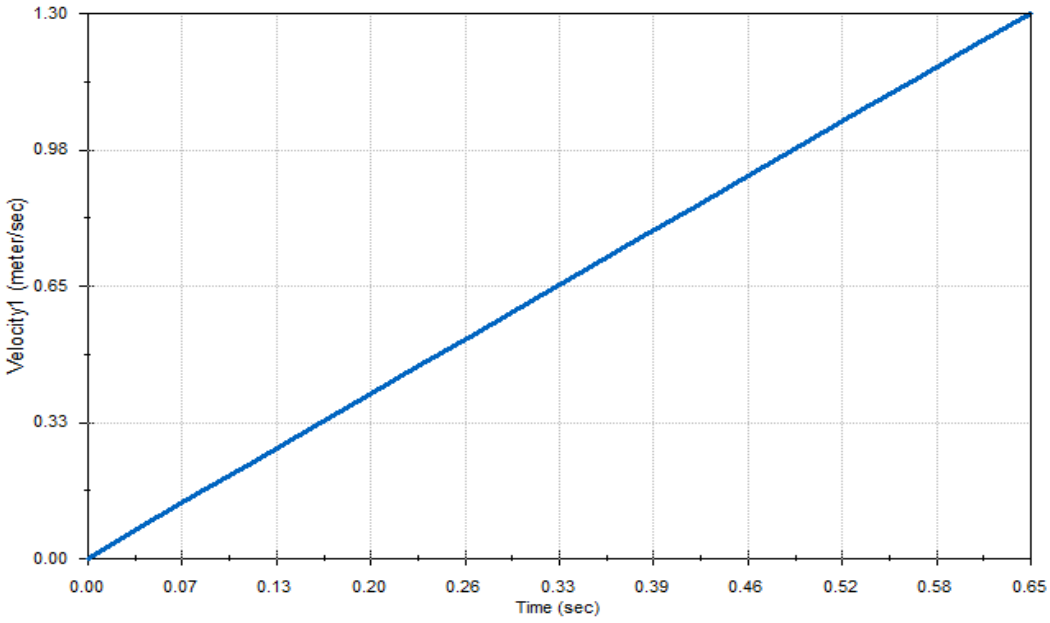
- Now you can play it and see how it behaves when a force is applied. You can drag the key point until when it reaches the end of the floor.

Advanced Lesson 1

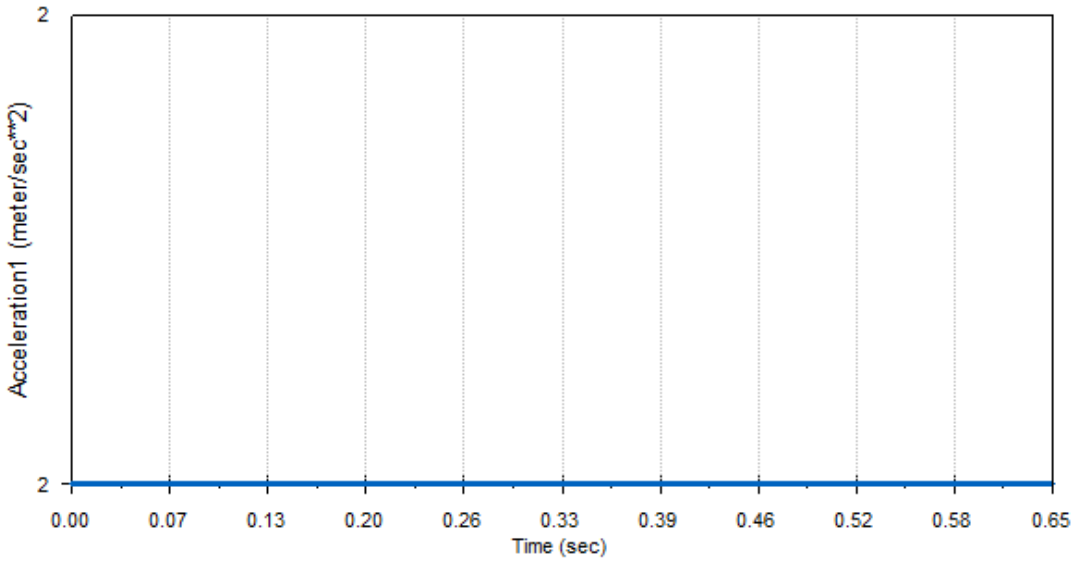
- You can get the results in a plot as shown below. Results and Plots → Select category → Select sub-category → Select result component. Then select the face which you want to get the results of. This would give the plot of the result versus time or else you select new results and change results instead of time. You can see the plot by expanding the results in the motion manager tree → right click the plot you want to see → Show plot. To see the data points in excel, right click on the plot and the click Export CSV.



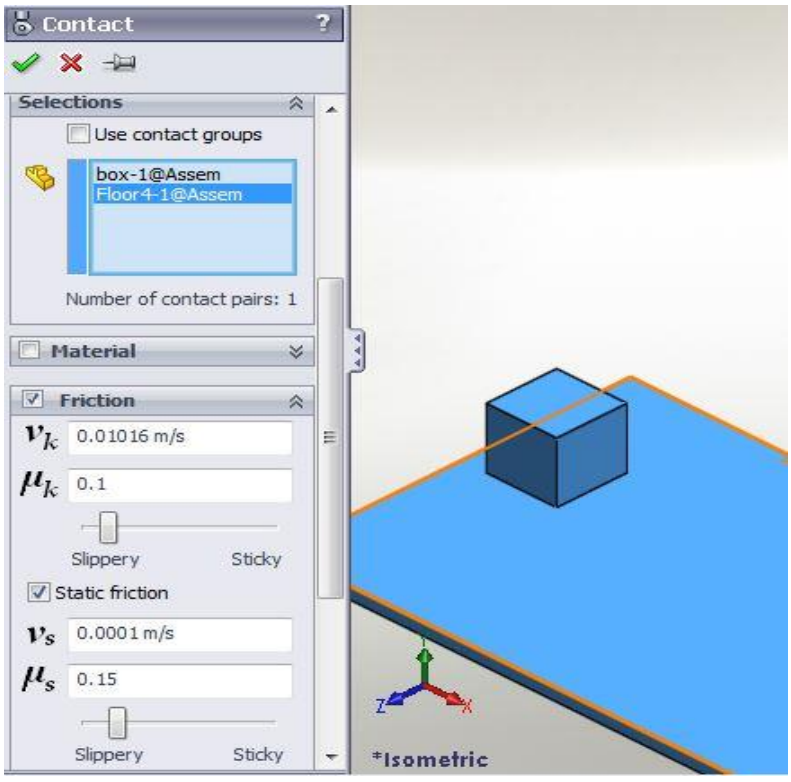
- Velocity vs Time plot (without friction)



- Acceleration vs Time plot (without friction)



- Add contact to use the friction features. Unselect the material option to edit the static and kinetic friction coefficients. If you want to choose the materials SolidWorks will set the friction values to match the materials. When working with friction, coincident mate should be either suppress or deleted from the motion analysis. Do not specify mass when working with friction. You can change the mass by creating a materian changing the density of it as shown in “Tips and Tricks” section.



Note: Please make sure to move the time bar in the timeline to initial (ie. 0 seconds) before you make any changes to your force, torque, or mates!

Exercise

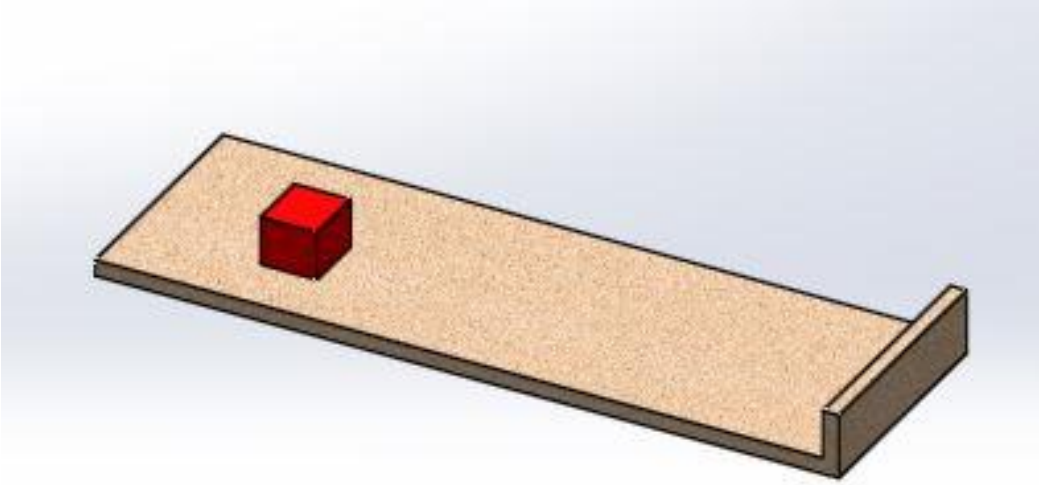
Do all this calculations and plots over 0 to 0.65 seconds.

1. Do the same problem with mass = 10 kg and force = 15 N without adding any friction (uncheck the friction option) and plot velocity and acceleration vs time.
2. Do the same problem with mass = 10 lbm and force = 4 lbf without adding any friction and plot velocity and acceleration vs time.
3. Do the same problem with mass = 4 kg and force = 20 N with μ_k = 0.25 and μ_s = 0.3 and plot velocity and acceleration vs time. (Note: When dealing with friction, please check the highlighted note in lesson 1)

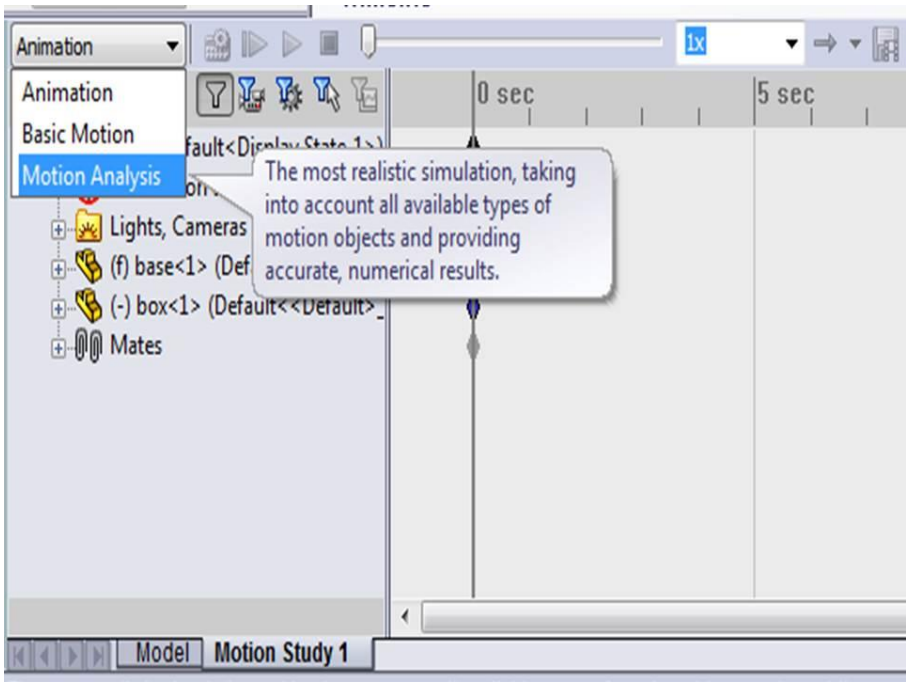
Lesson 2

This lesson will help you to get familiar with simulation of a spring. You can download the part and assembly files from the website under class materials.

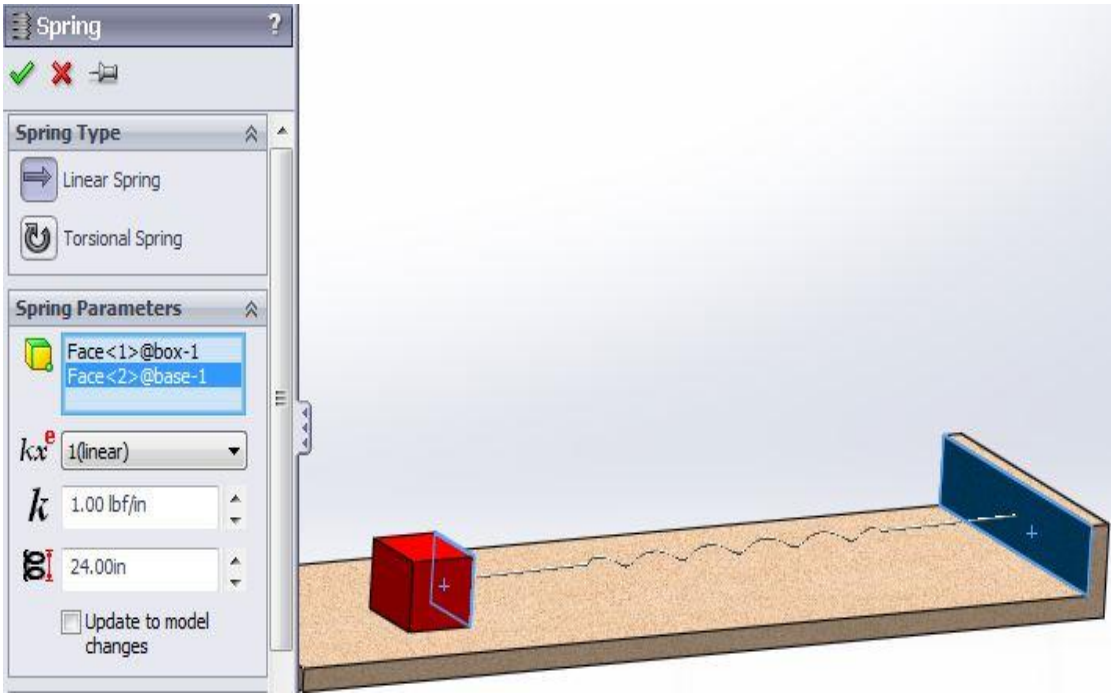
- Open the assembly file → Do the similar mates as in the lesson 1



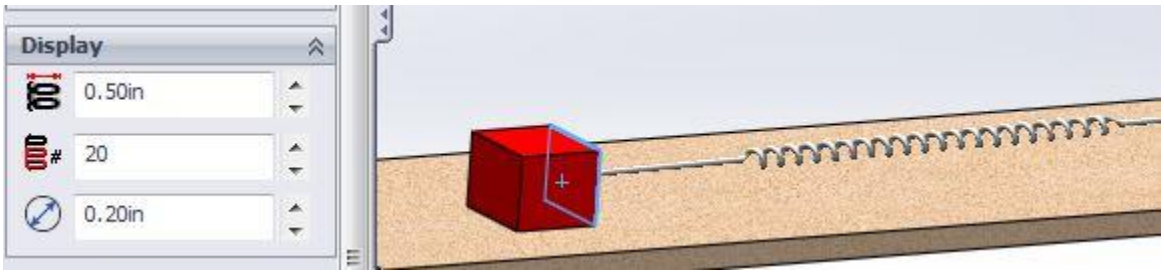
- Click the motion analysis option as shown.



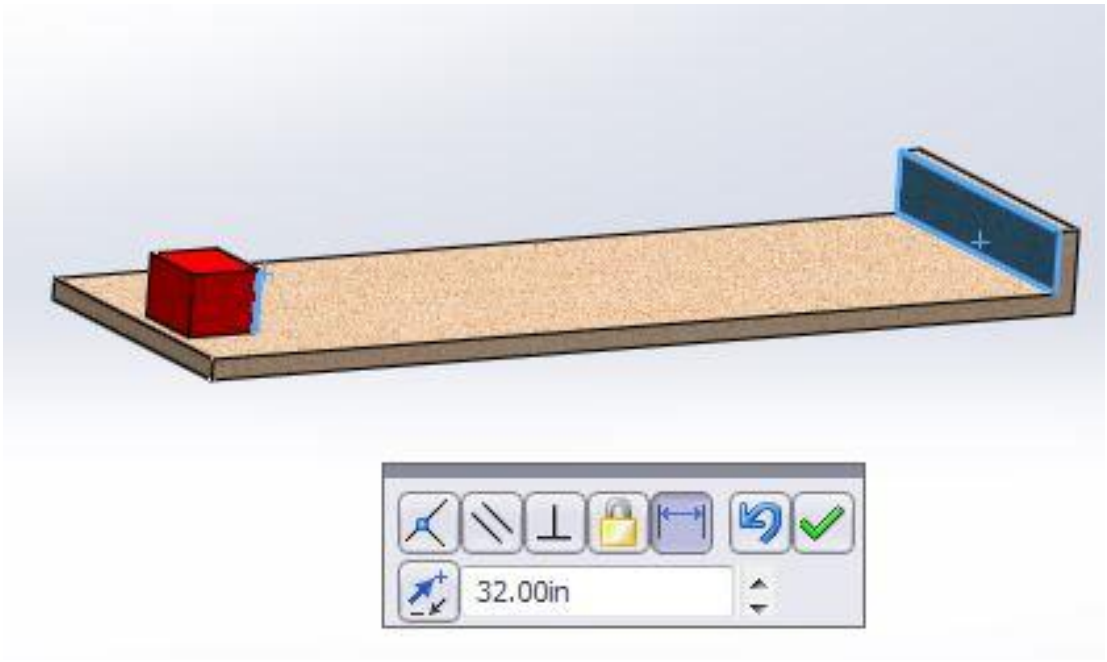
- Add a spring to it by selecting the face of the box and the face of base as shown. Then you can change the spring stiffness and unstretched length of it as shown.



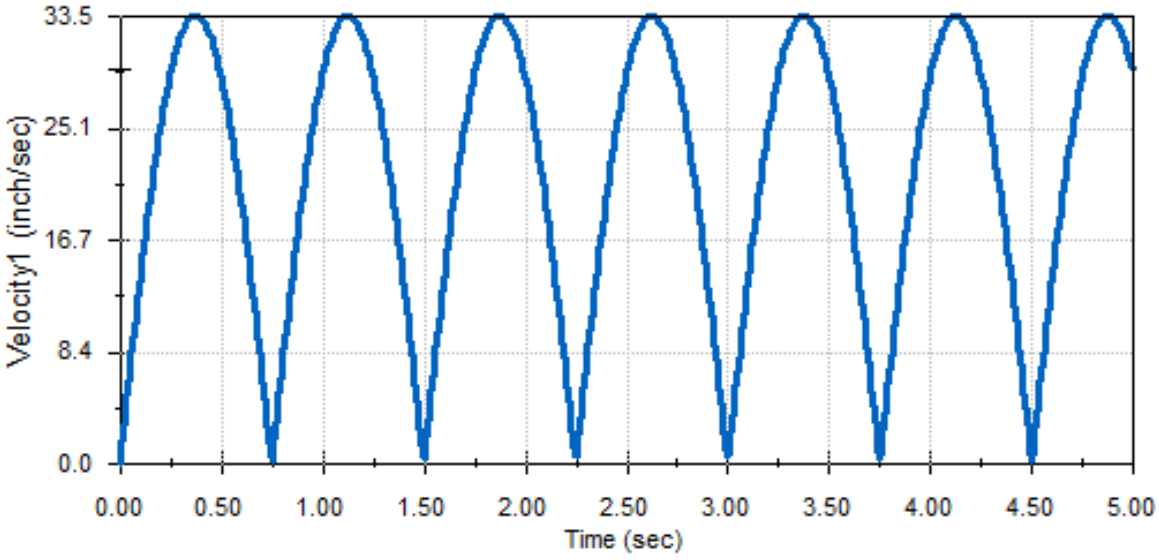
- You can change the display of the spring such as diameter, thickness, and number of cycles. This part will not affect any mechanical properties of the spring.



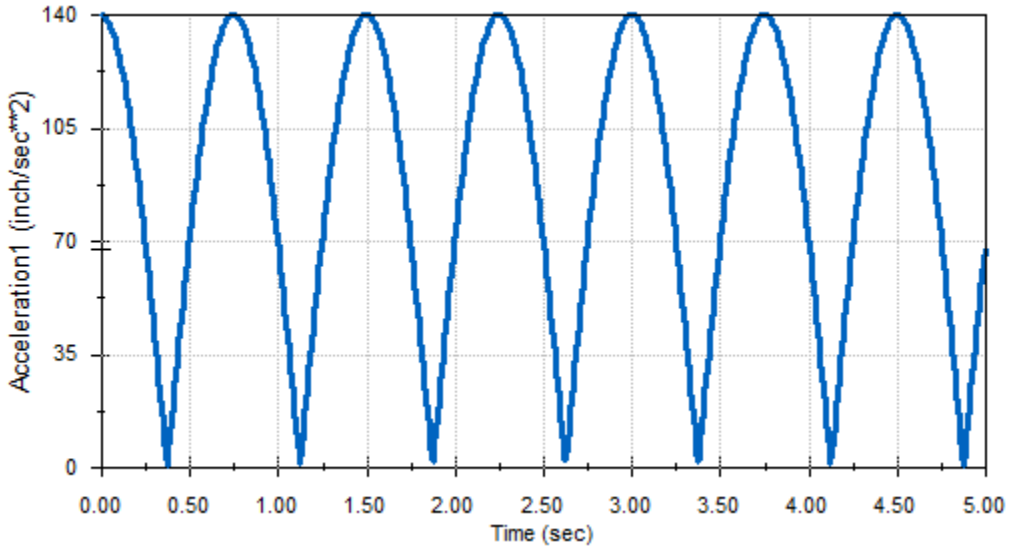
- Now you can change the initial length of the spring by adding a mate to it. As shown here, add a distance mate in between the two faces. Here I enter the initial length longer than the unstretched length to give an oscillation. Make sure to suppress (Right click on the mate and then select suppress) or delete the mate from the motion study before you calculate motion or else the box will not move.



- Assign mass (10kg) and Calculate motion.
- In addition you can add friction as shown in lesson 1 and then plot the results of desired parameters, but you need to consider the fact that you can't assign mass and you have to create a new material as shown in "Tips and Tricks" section.
- Velocity vs Time plot



- Acceleration vs Time plot



Note: The spring won't be on display unless you click the spring on the motion manager tree while it is playing.

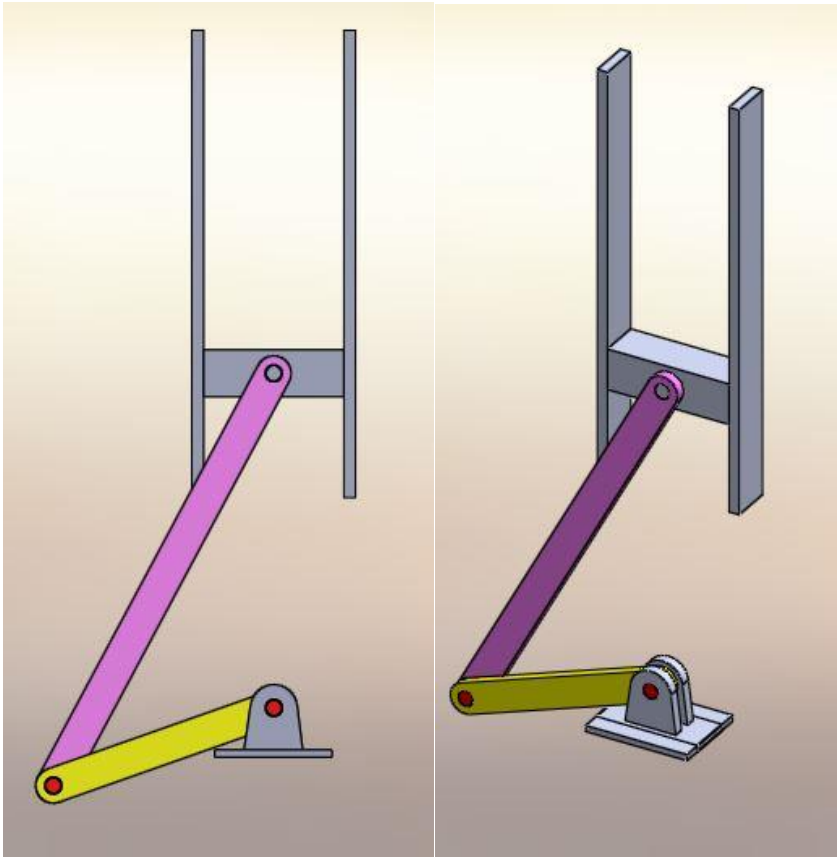
Exercise

1. Do the same problem with mass = 5 kg and plot velocity and acceleration vs time.
2. Do the same problem (mass = 10 kg) with spring constant = 200 N/m.
3. Do the same problem (mass = 10 kg) with initial length = 0.4m keeping the unstretched length the same.
4. Do the same problem while setting the unstretched and initial lengths equal to 0.5m and applying a 5 N force in the positive x direction.

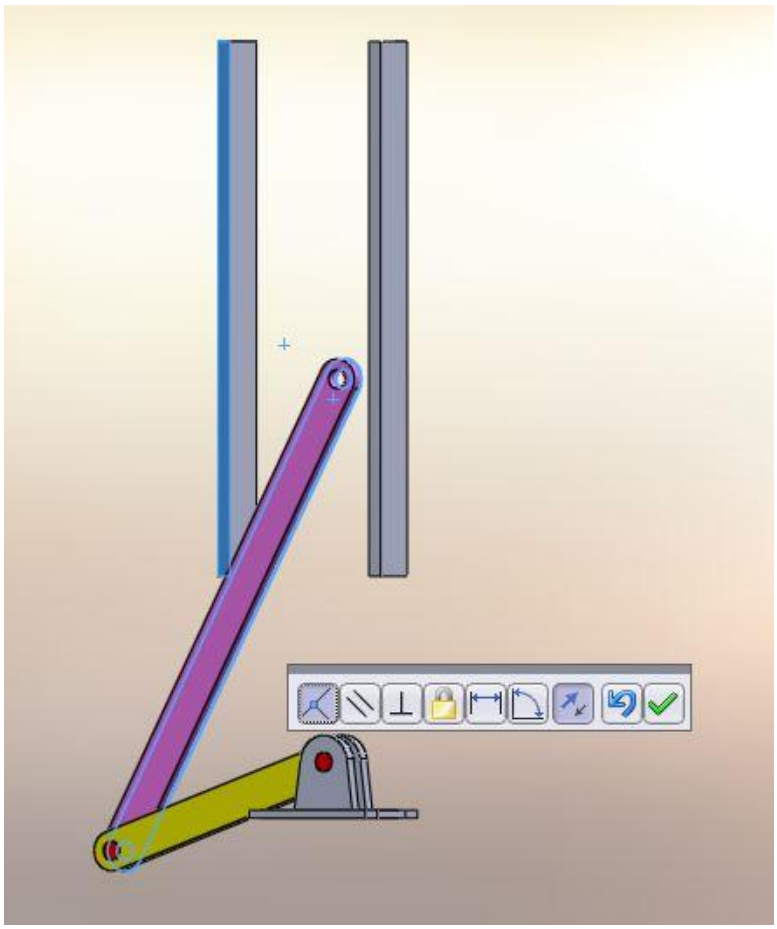
Lesson 3

This lesson will allow you to get familiar with motors. You can download the part and assembly files from the website under class materials.

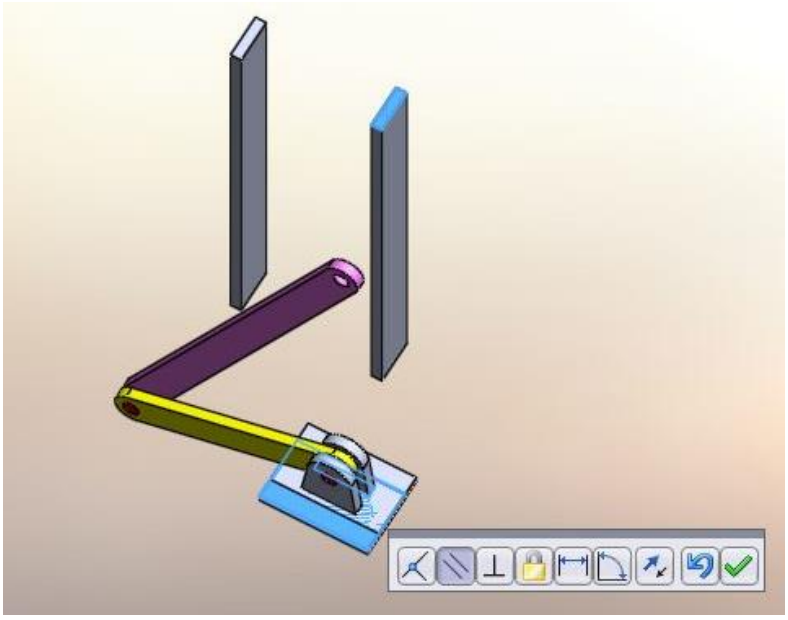
- The first few mates are exactly the same as shown in “Introduction to Mates” at the beginning. The images show the completed assembly.



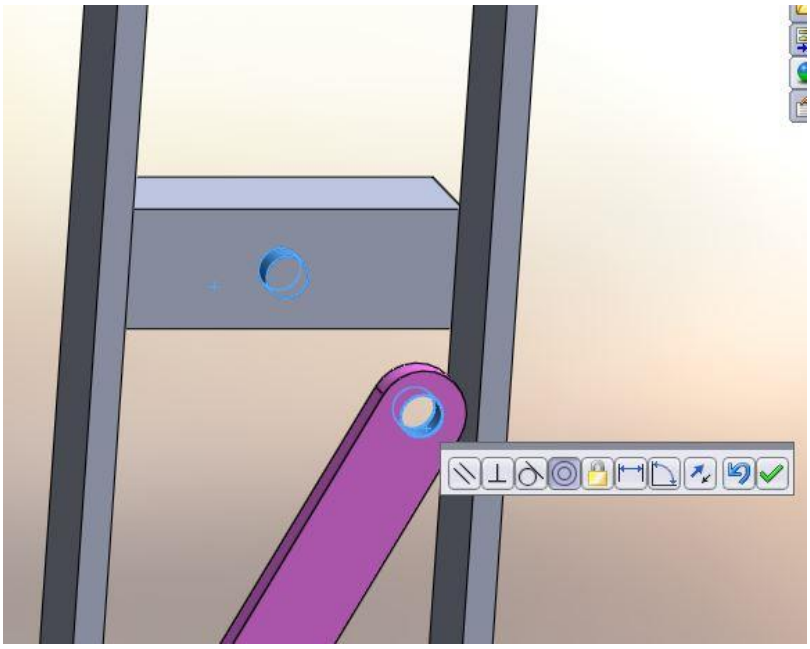
- After assembling the pin holder with the two bars, insert component → Insert Slide part file. Then in mates, click the faces as shown which would select the coincident mate by default.



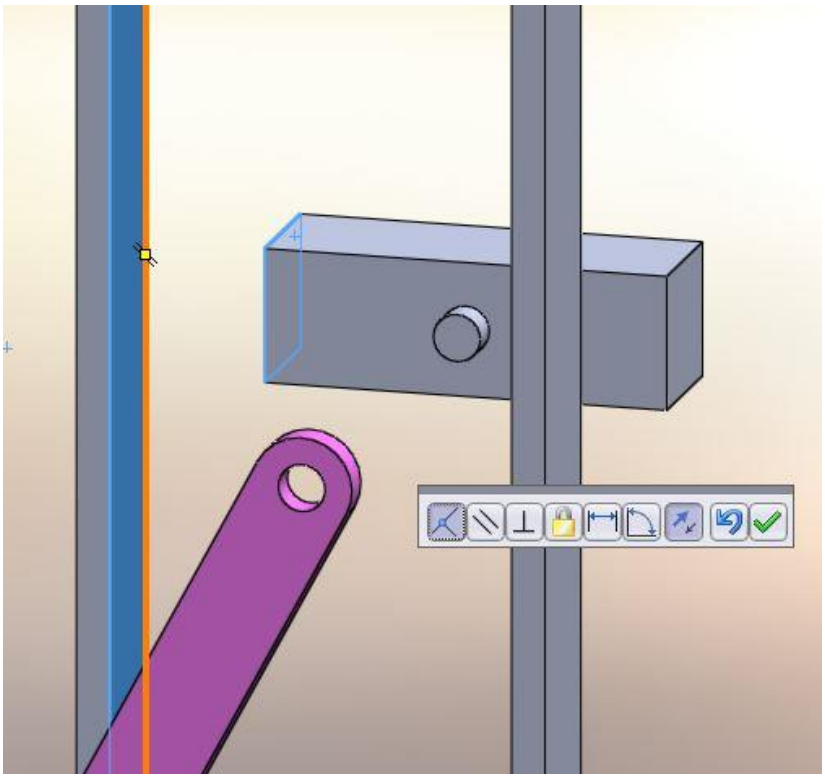
- Click the faces as shown which would select the coincident mate by default, but change it to parallel mate as shown.



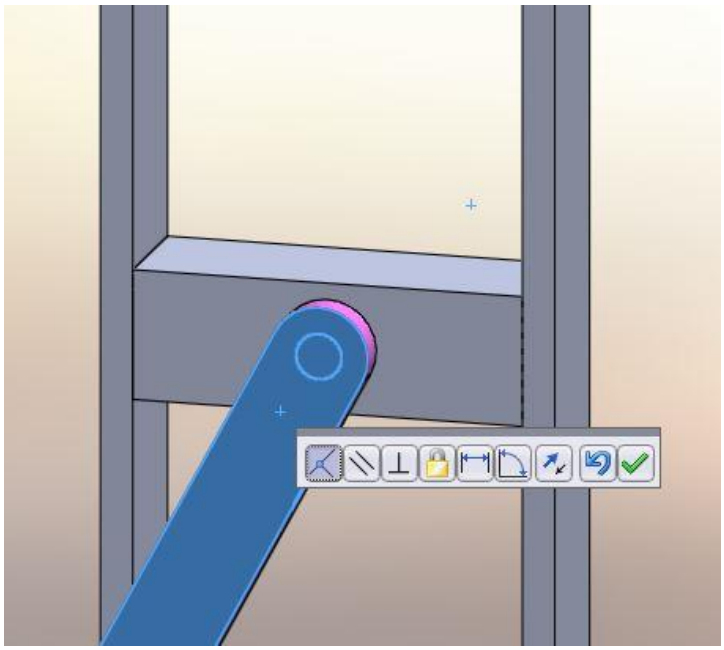
- Insert the component sliding box. Then click the cylindrical faces as shown which would select the concentric mate by default.



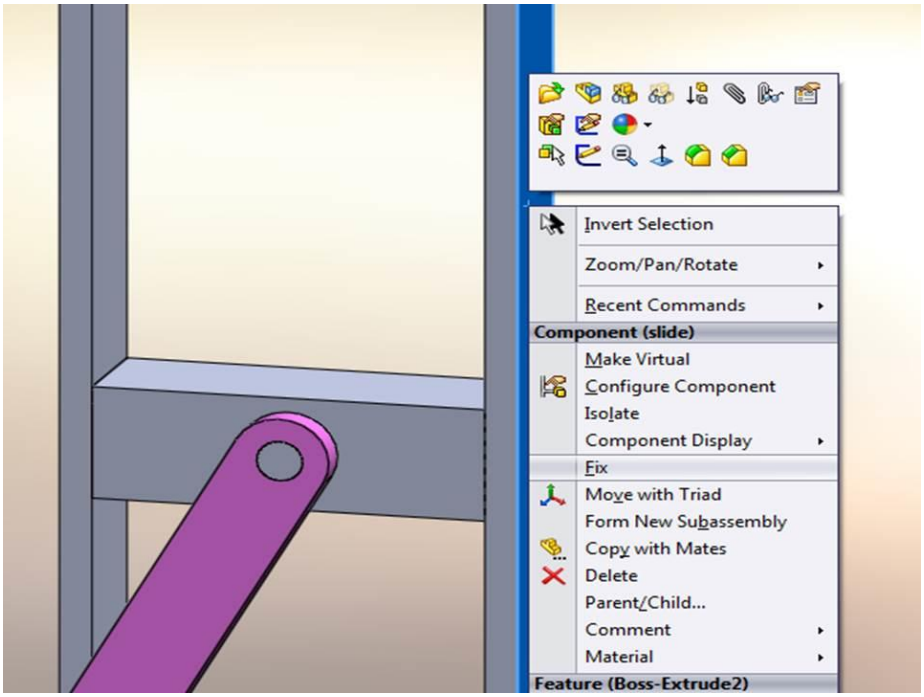
- Select the faces as shown which would select the coincident mate by default.



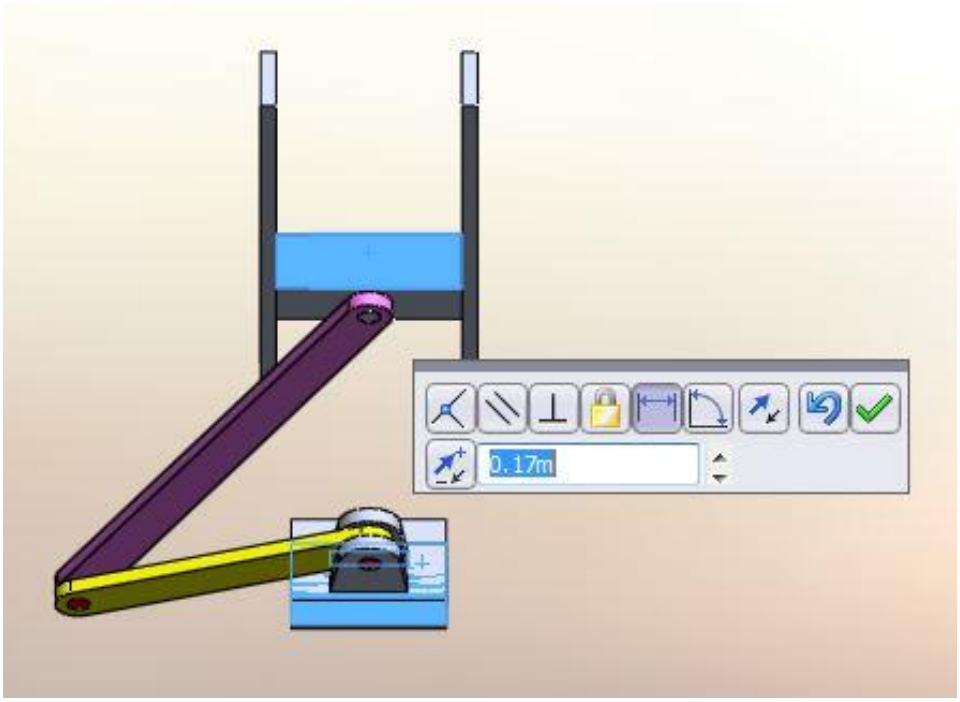
- Now select the circular face of the pin on the sliding bar and the front face of the bar as shown which would select the coincident mate by default.



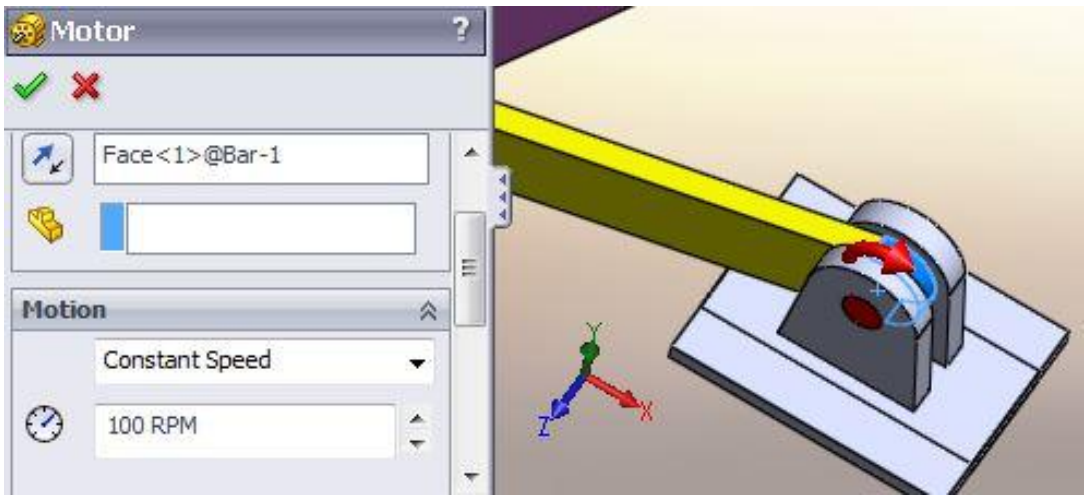
- Right click anywhere on the part Slide and select fix to make that part fixed.



- Now select the top face of the sliding box and the pin holder as shown. Then select the distance mate and enter the values as shown to make it start at a lower position.

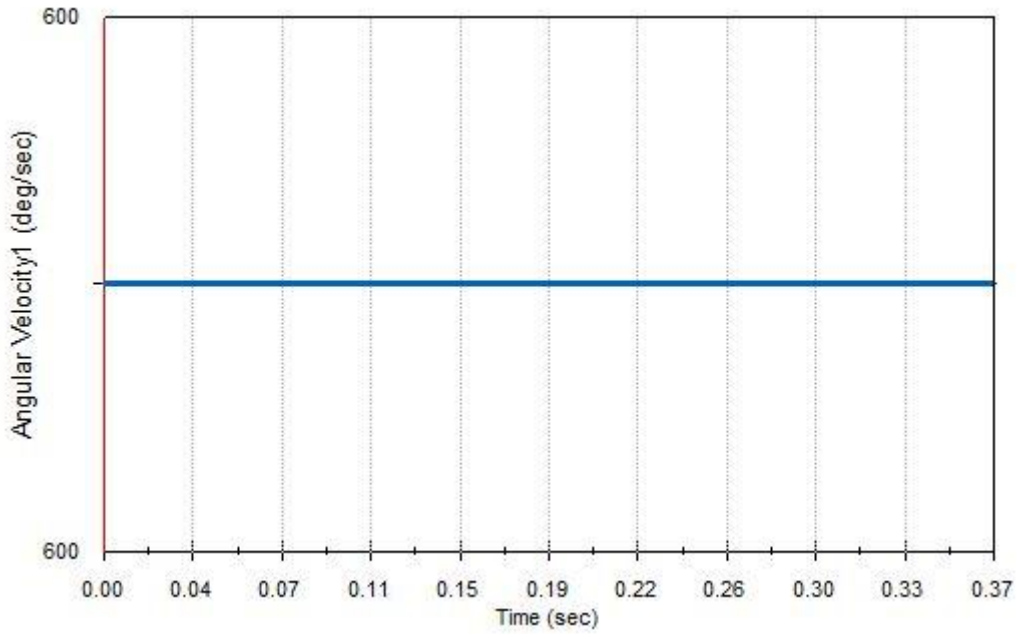


- Click motor in the motion tab to give the rod an angular velocity. Select the curved face of the rod as shown and give a constant angular velocity of 100 RPM.

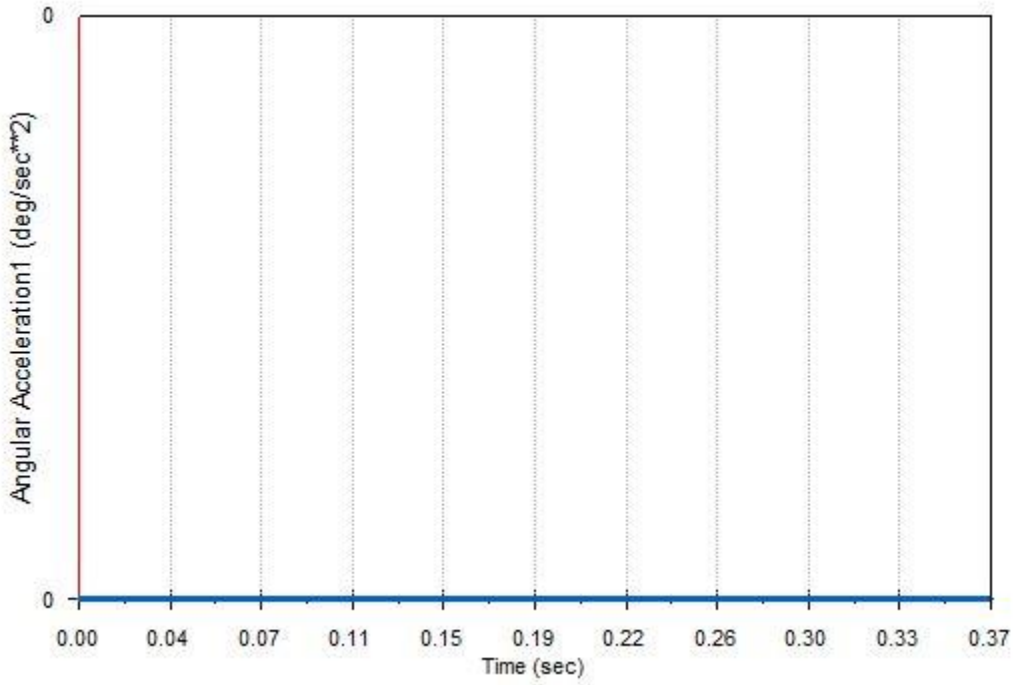


- Assign 5 kg mass for the block and then go to the motion analysis tab and click calculate.

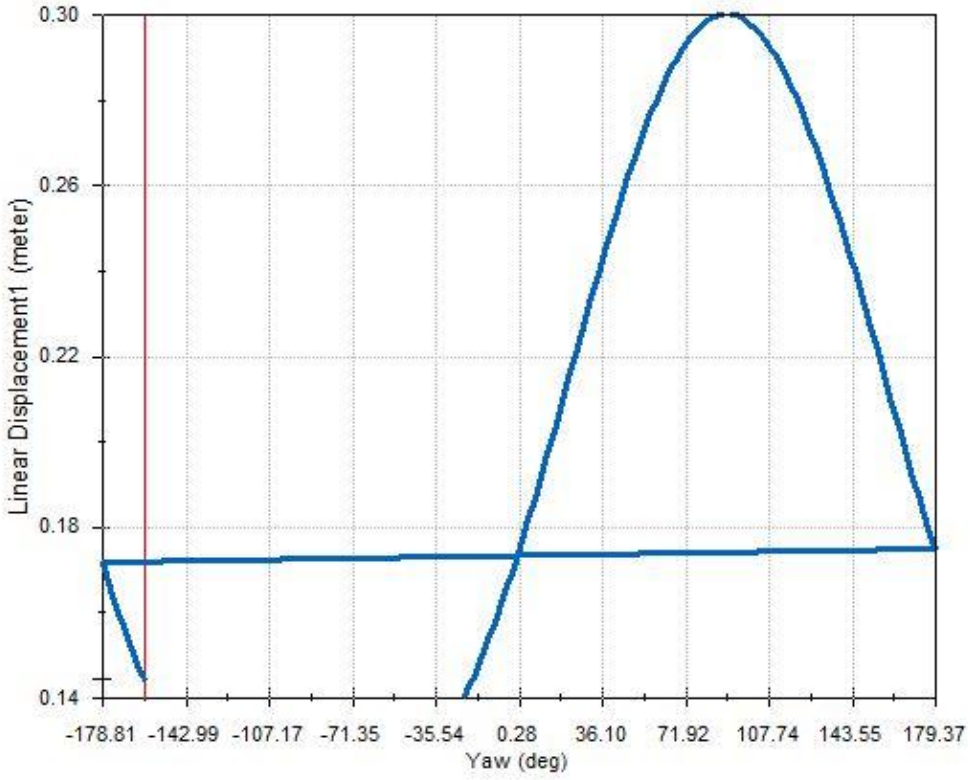
- Angular Velocity vs Time plot.



- Angular Acceleration vs Time plot.



- Displacement of the Sliding Box vs Angle of the rod plot.



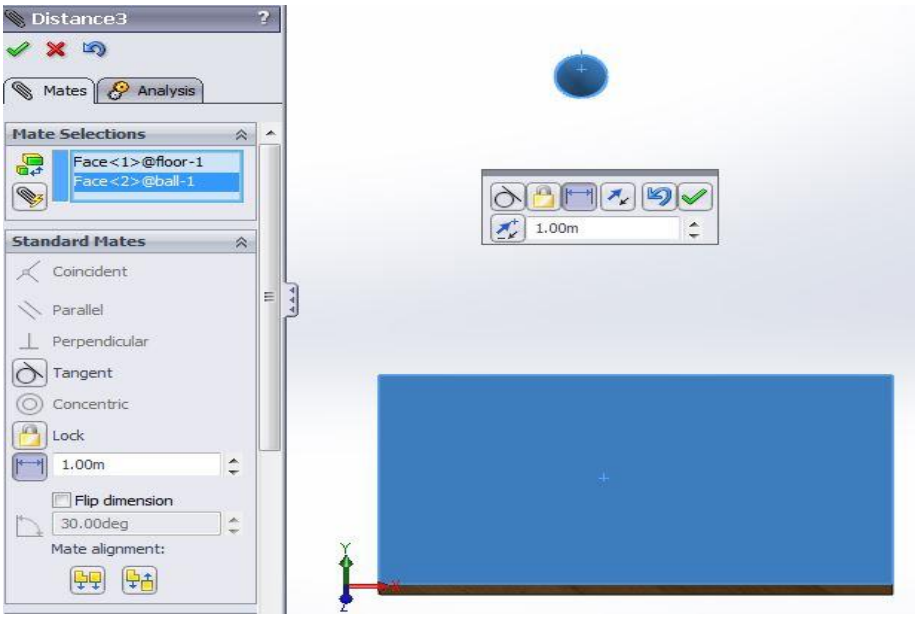
Exercise

1. Do the same problem with a 10kg mass box and show all three plots.
2. Do the same problem with the same mass but 150 RPM constant speed and show all three plots.
3. Do the same problem with 5 rad/s constant angular velocity and show all three plots.

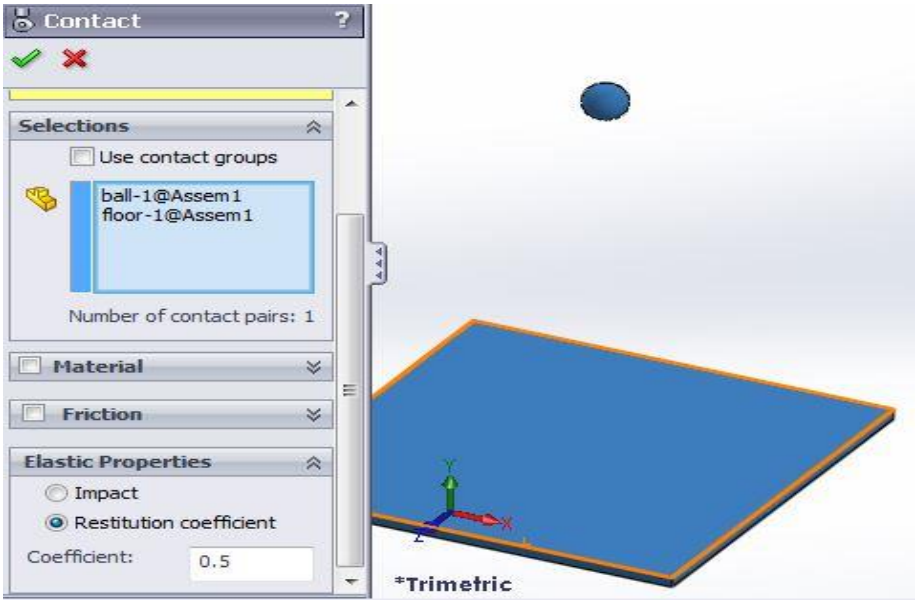
Lesson 4

This lesson will allow you to get familiar with a simple impact situation. You can download the part and assembly files from the website under class materials.

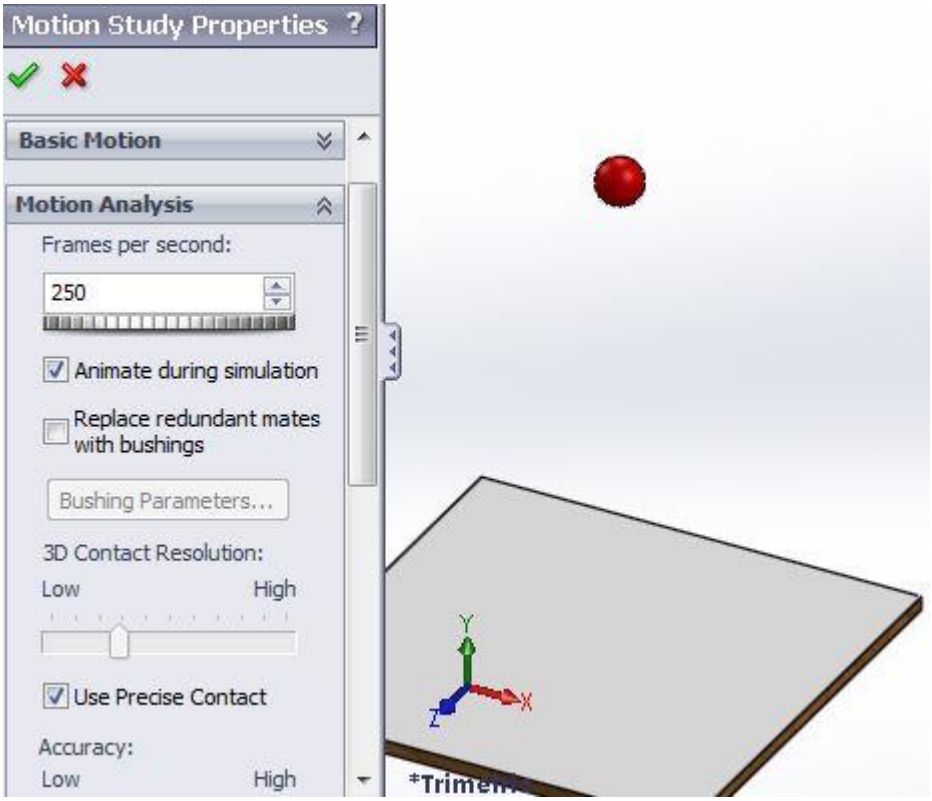
- Make the assembly file and make sure the ball is above where the floor is by selecting the different views to make sure of its position. Then create a distance mate between the ball and the floor as shown (1m) in the model tab.



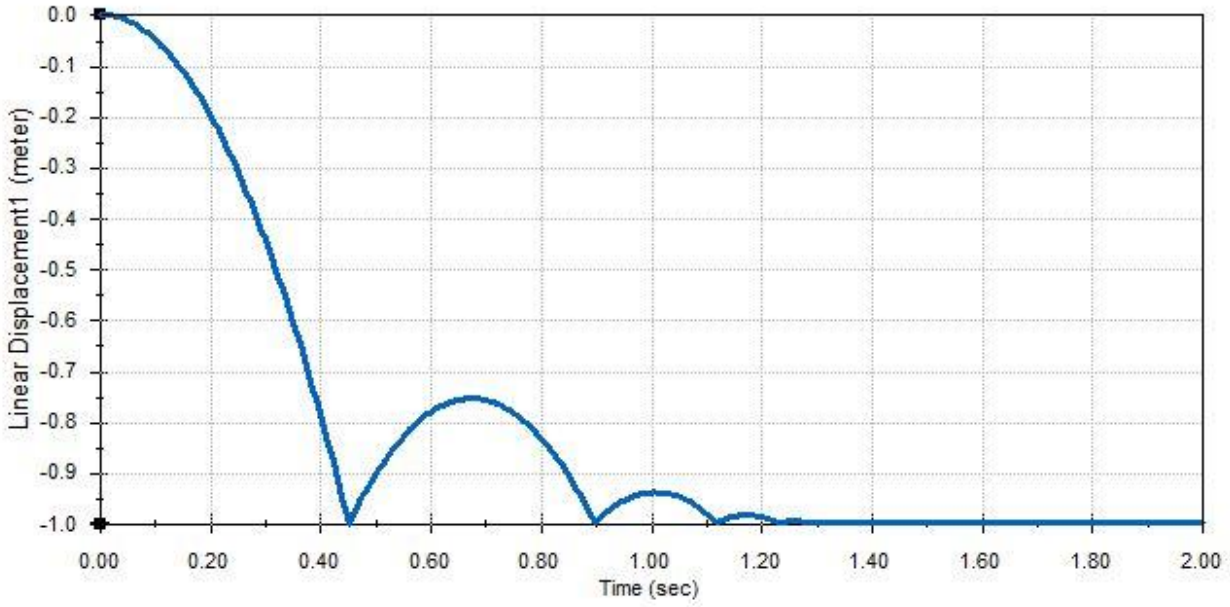
- Add solid body contact between the ball and the floor. Check the restitution coefficient (0.5) option.



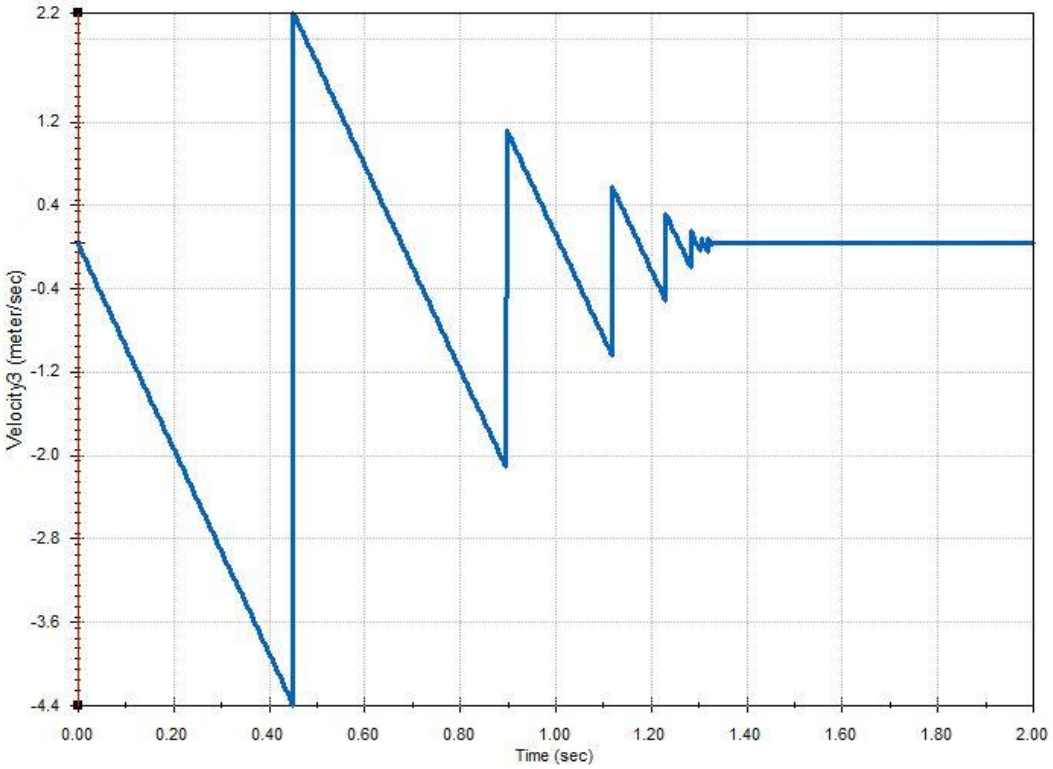
- The default simulation setting sare often not accurate enough to capture impact events. There are two ways you can change the defaults. You can use either check the “Use Precise Contact” option or increase the frames per second. The preferred solution is Use Precise Contact.



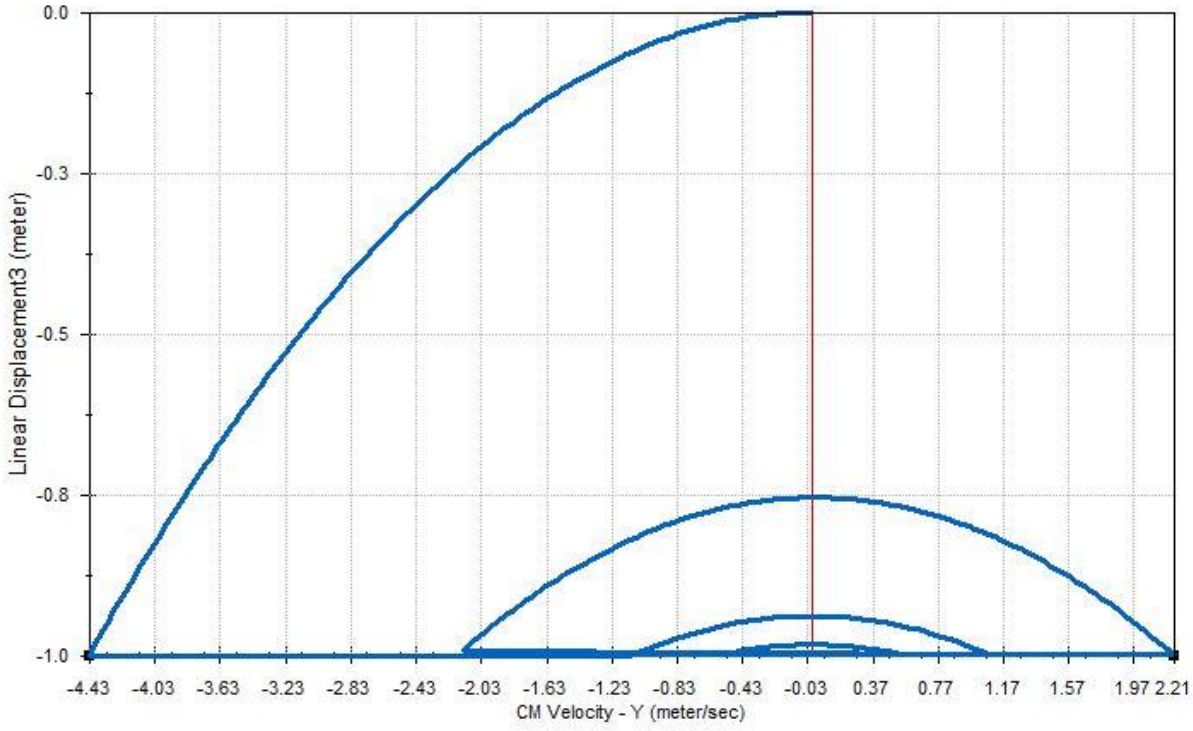
- Calculate the motion and plot the results of the displacement of the ball vs time.



- Linear velocity vs Time plot



- Linear Displacement vs Linear Velocity Plot

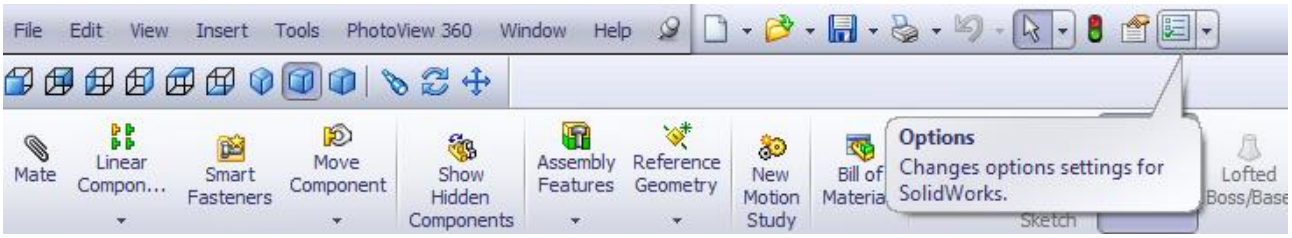


Exercise

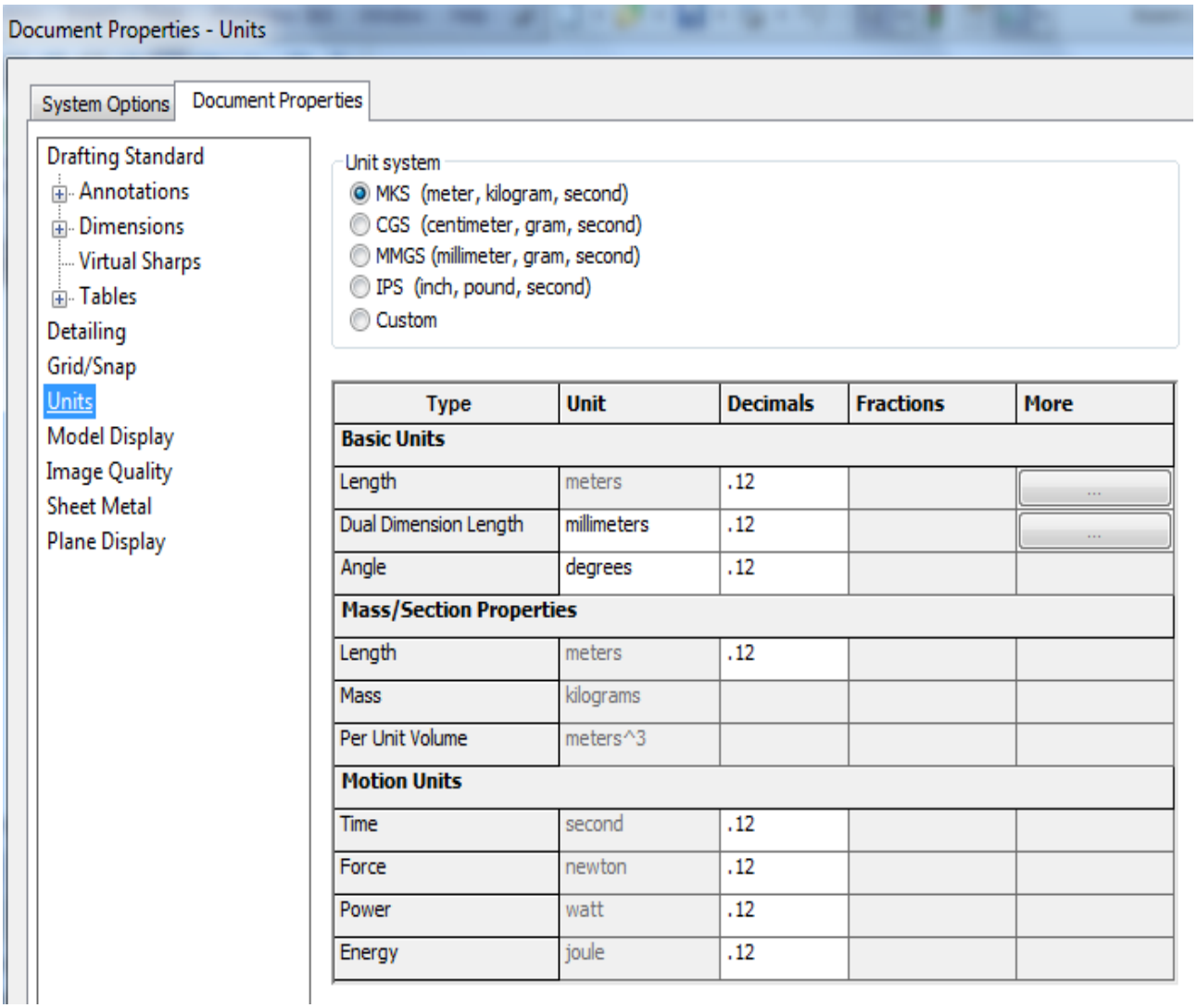
1. Do the same problem with a restitution coefficient of 0.6 and plot the displacement of the ball vs time, the results of linear velocity vs time, and the results of linear displacement vs linear velocity.

Tips and Tricks

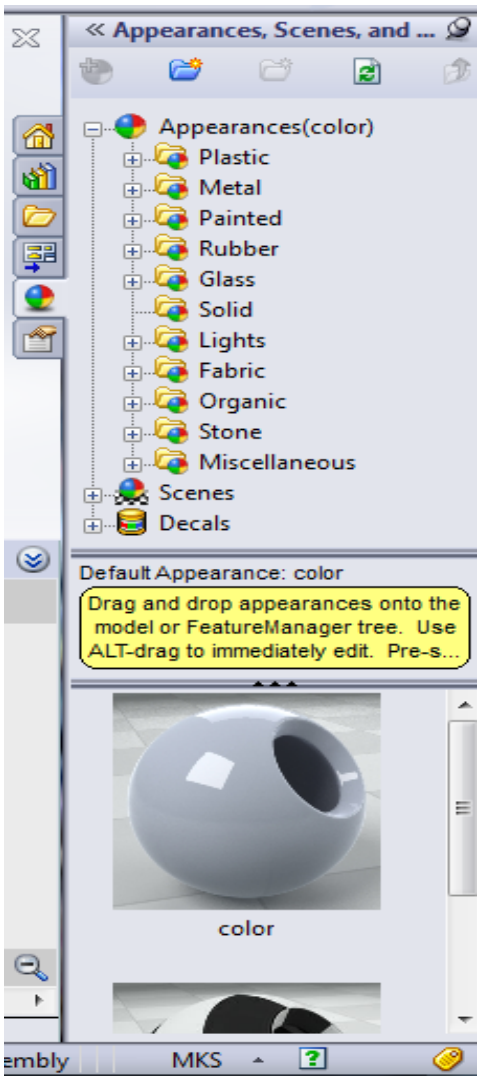
- To change units, click options as shown.



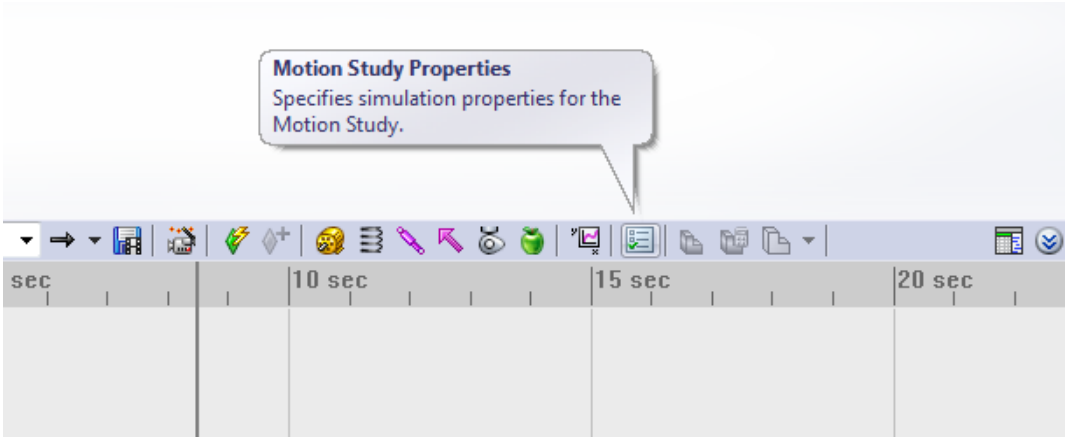
Then you can change units as you need as shown below.



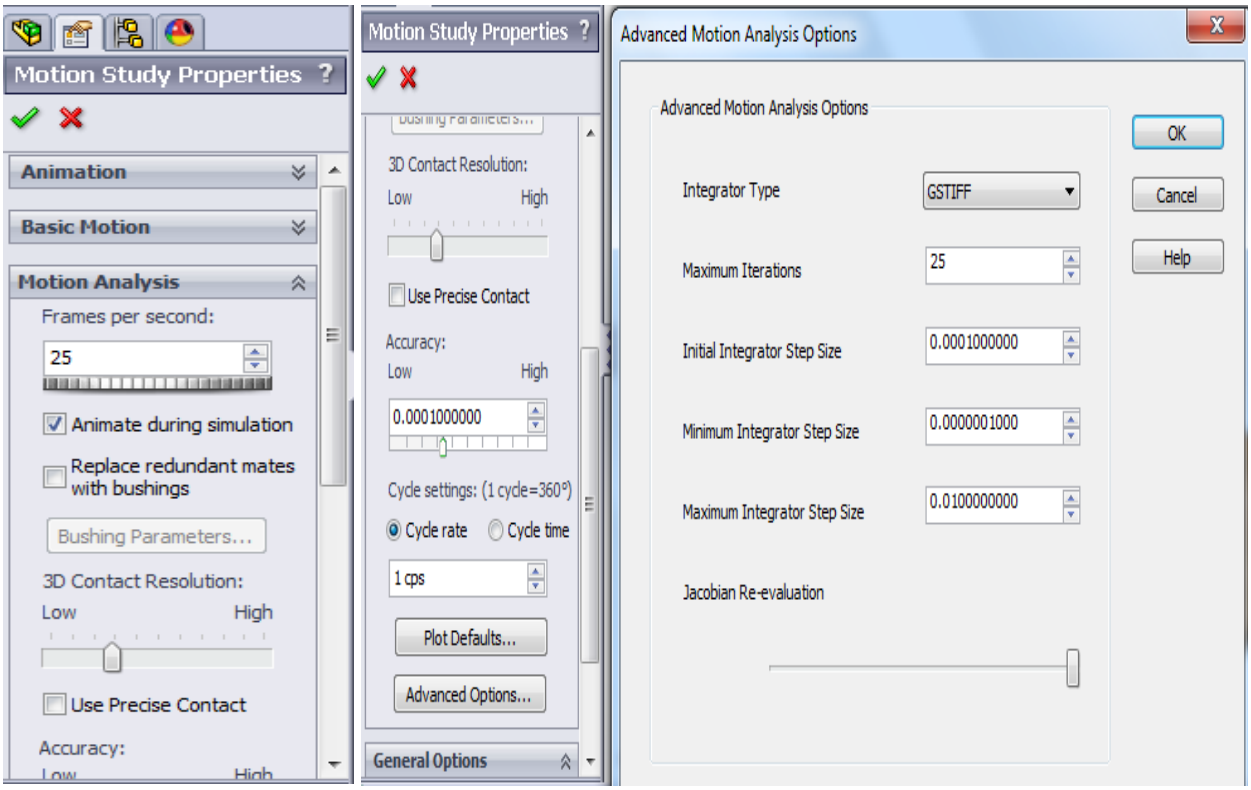
- To change the material, drag and drop the appearance on the part you want to change the material of.



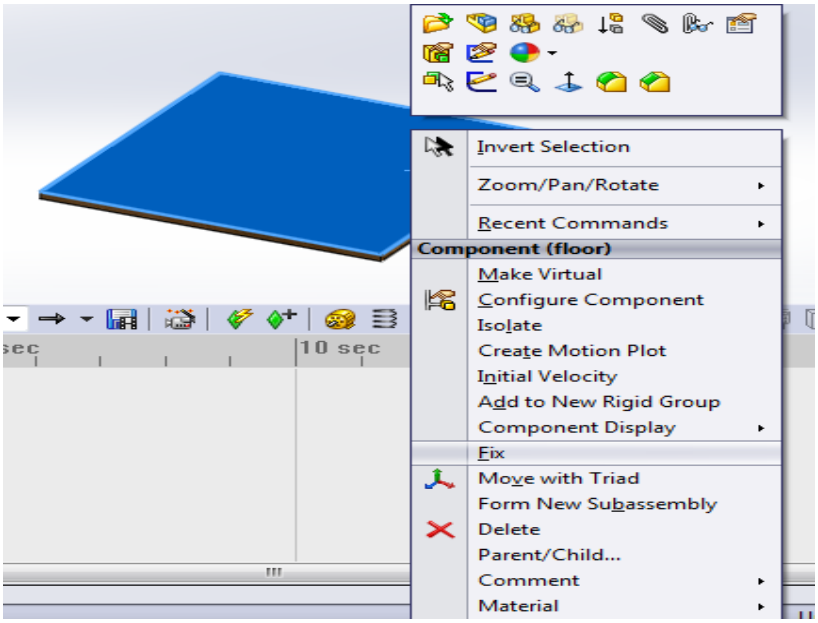
- Click the icon as shown to change the Motion Study properties



You can make the motion smoother by increasing the frames per second. You can make the accuracy higher and change the solver by clicking 'Advance Options' (Integrator type) to make your simulation work.

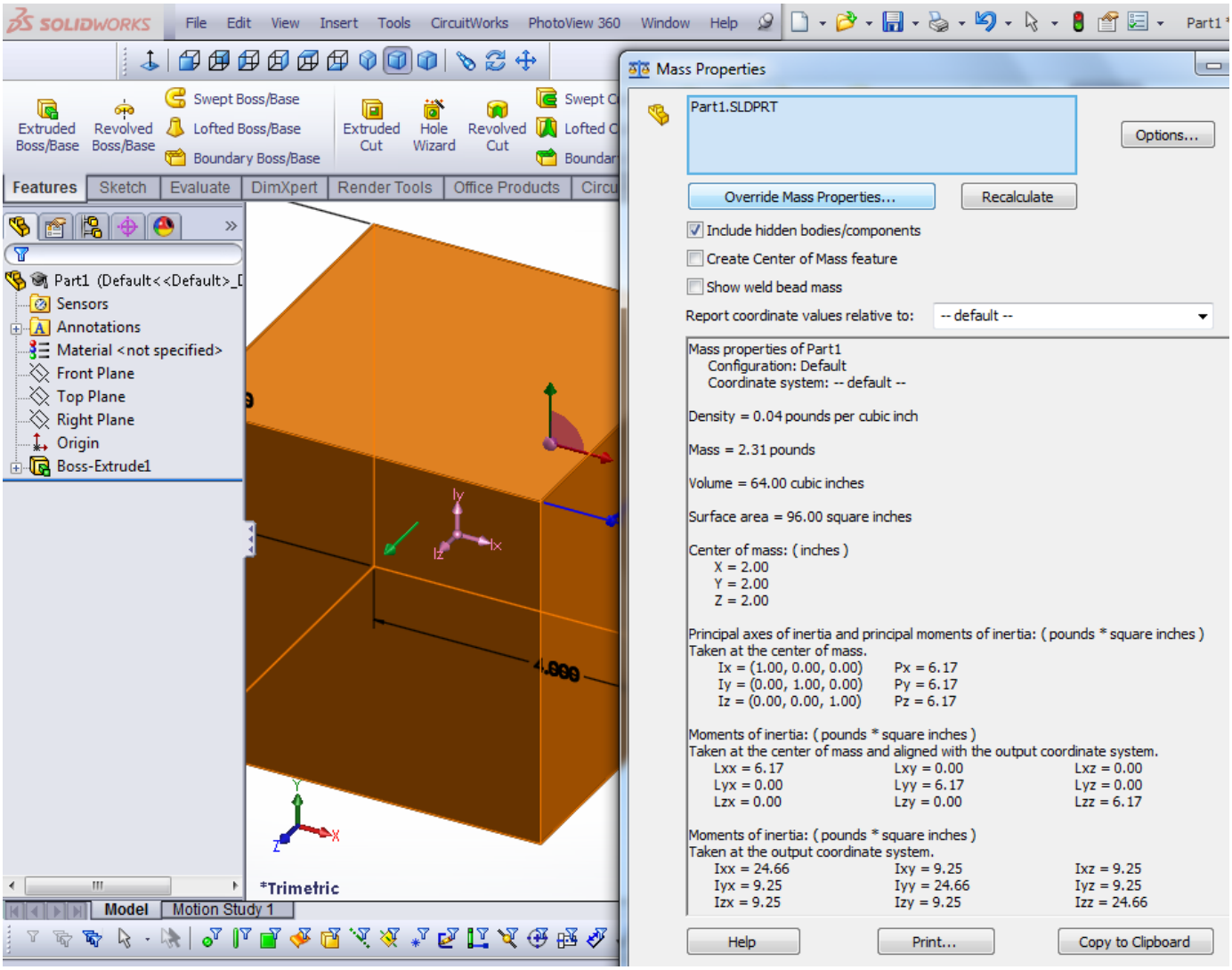


- Fix and float : Fixed parts are incapable of moving, while moving parts must be floating. First import the part file that needs to be fixed so by default it will be fixed. The parts you import after that would be in float mode so you can freely move them around; use right-click → Fix to make it fixed as shown.

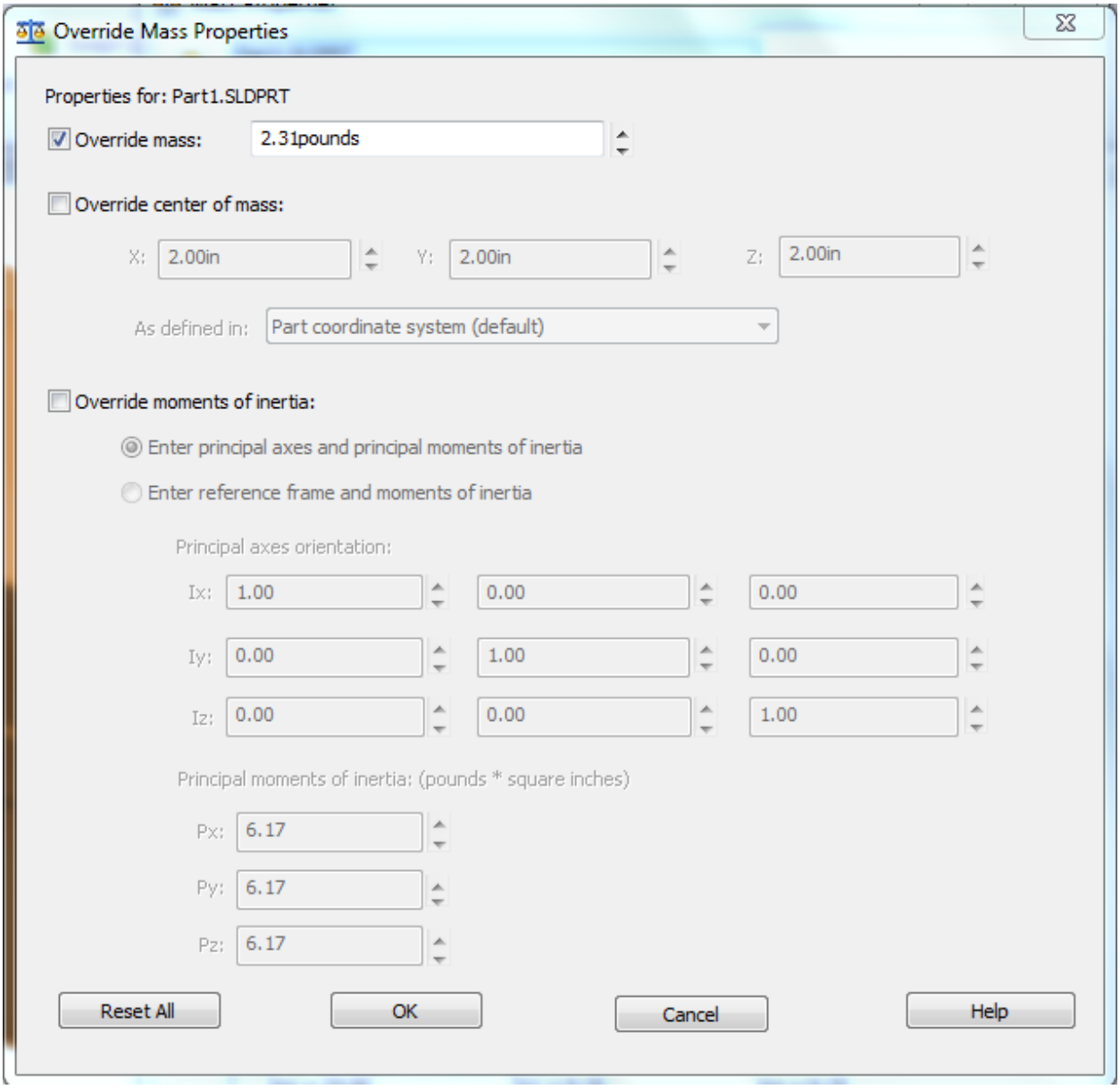


- SolidWorks acts unusually sometimes when you try to change the mass manually, particularly in problems with impact and friction involved. In these cases the preferable way to change mass is to create a new material and change the density according to the volume to obtain the desired mass.

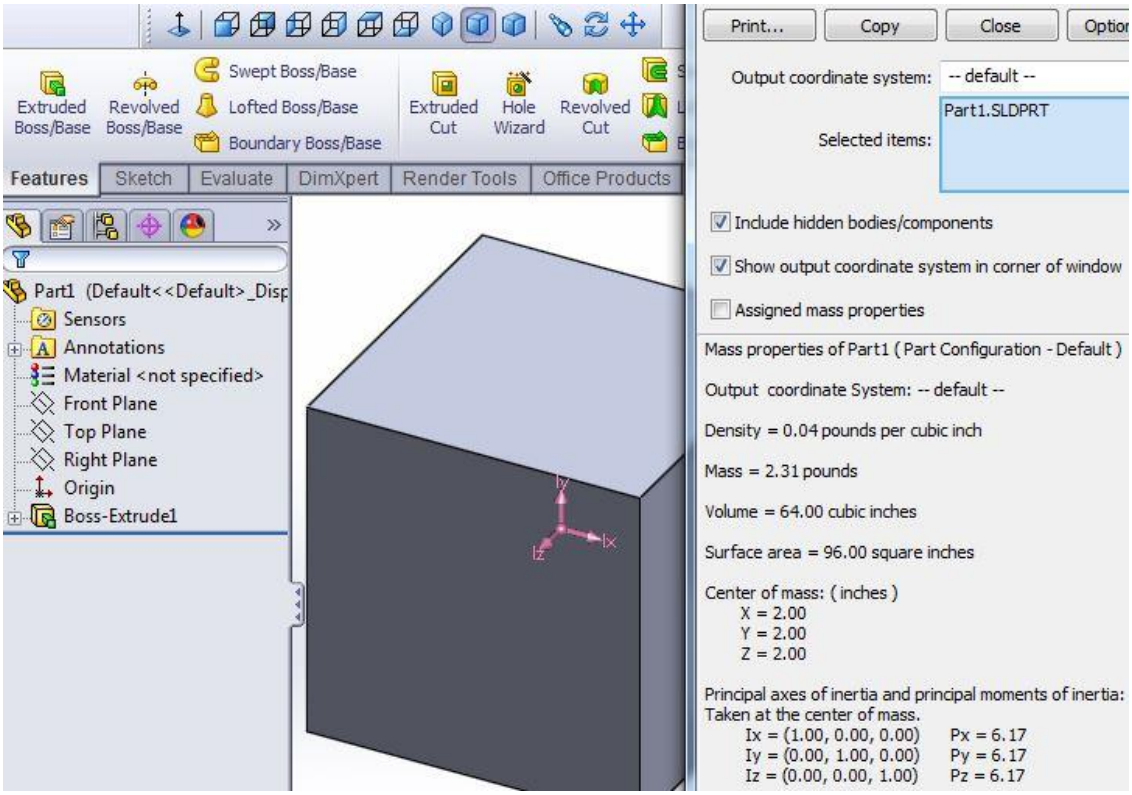
  Mass will be assigned by default as soon as the object is created. To access mass properties go to tools → Mass properties and you will see something similar to the one showed in image bellow. To edit mass properties click on “Override Mass Properties”.



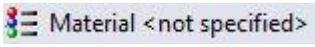
Mass, center of mass, and moments of inertia can be changed by accessing Override Mass Properties as shown below.



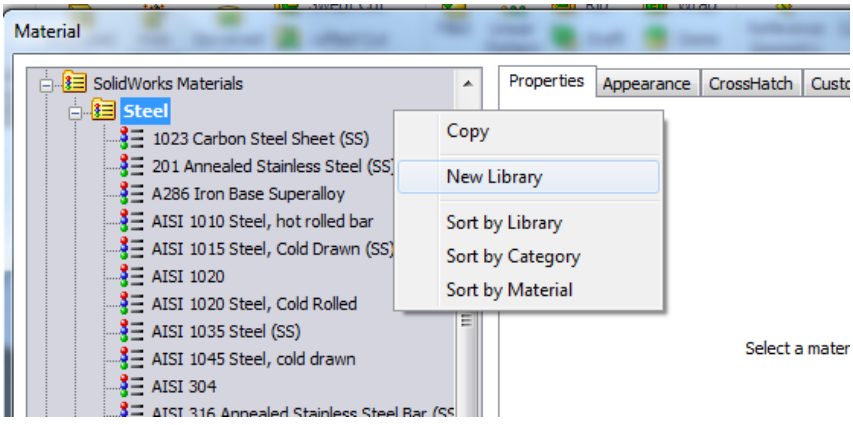
This is the appearance in SolidWorks 2012 version. In this check “Assign mass properties” to change mass.



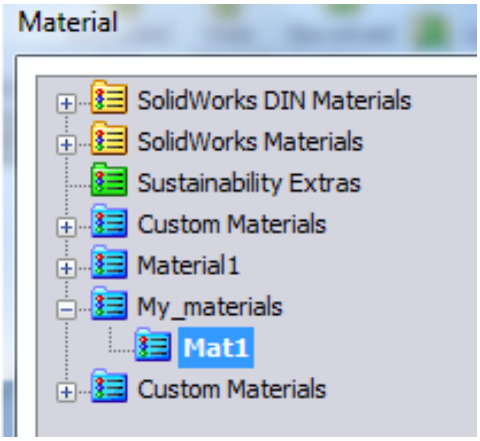
- If you see strange behavior with friction or impacts, you need to create a material to change the mass instead of selecting the “Override Mass Properties” or “Assign mass properties”. The steps are shown below with the help of pictures.

  First right click on the material 

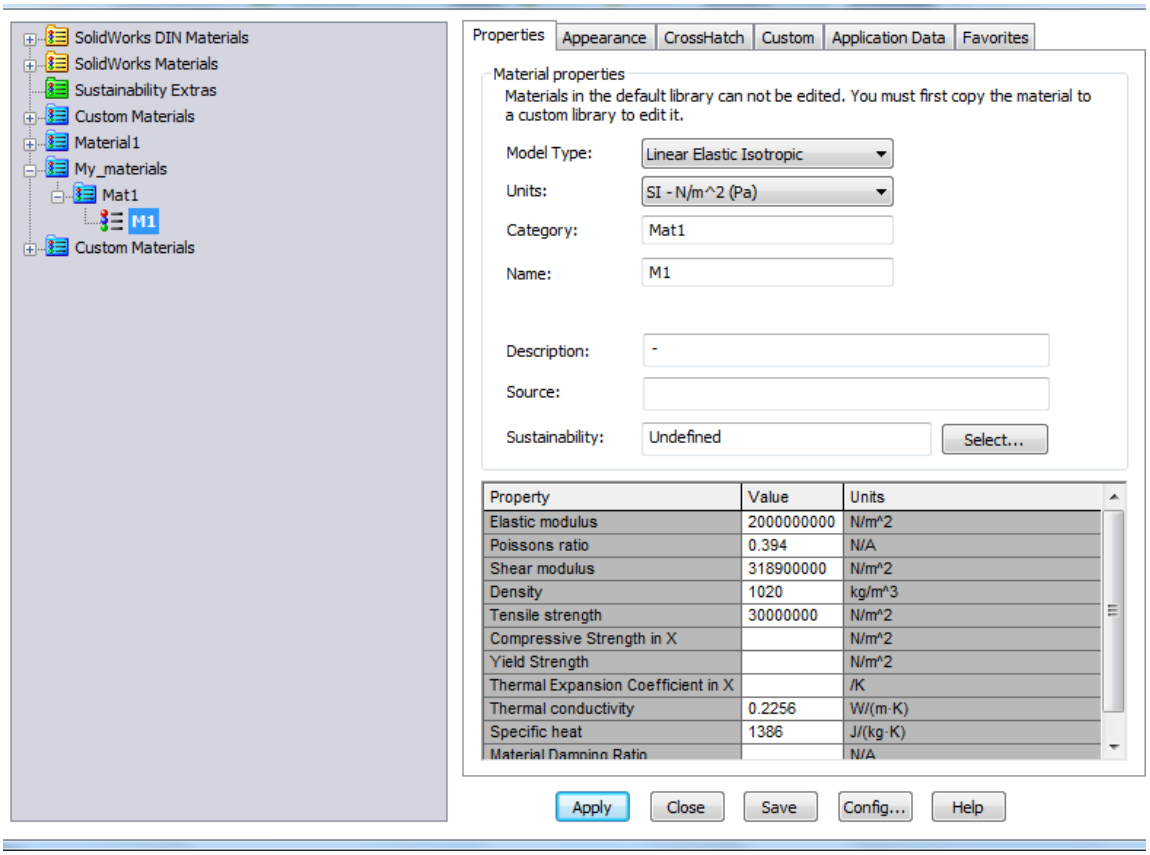
→ Edit material. Then the following tab will appear. Right click anywhere on the left side →select New Library.



  Then name your library and save it (For this example I have named it as ‘My_materials’). Then right click the library you created → select New Category (I named it as Mat1).

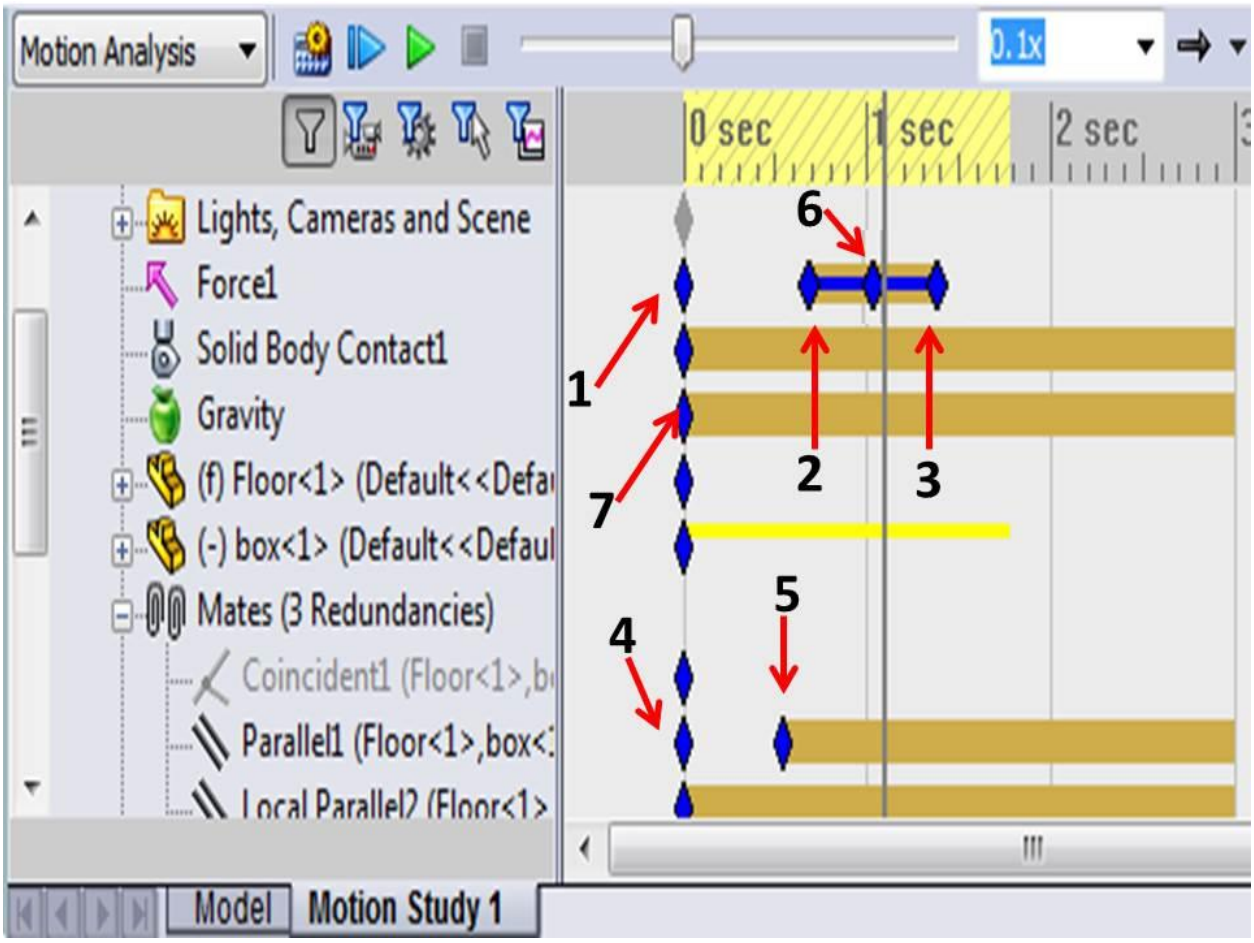


Then right click on the category you have crated and select 'New Material'. Name it and click the Properties tab as shown.



Now you can change the properties of the material shown in the 'Value' column; double click to edit. You will probably only change the density to get the desired mass and click 'Apply'. You can also change the units by clicking the drop-down arrow.

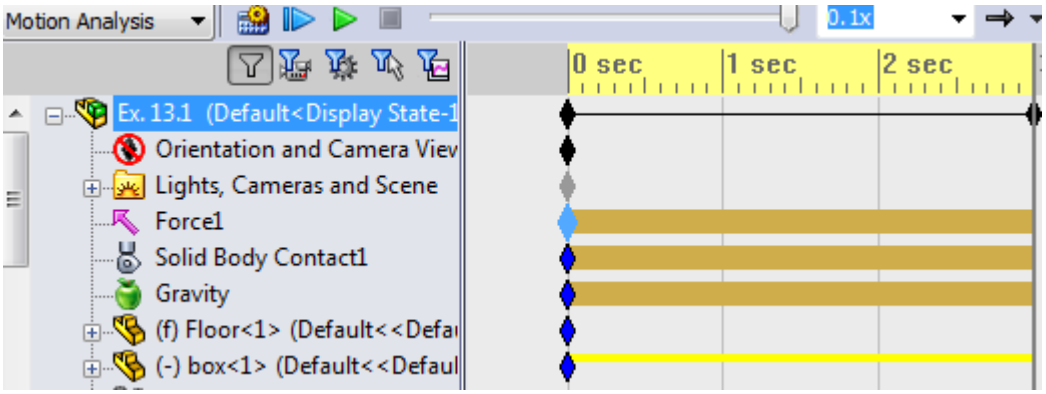
- Time Frame and Key Points



The above figure shows some typical errors in key frames when dealing with motion analysis. As you can see, key points 1, 2 and 4, 5 are discontinuous. This means the action is not active in the region, for instance the force is not acting from point 1 to 2.

Key points 2 and 3 imply that the force is active. Meanwhile notice that there is a key point 6 in between 2 and 3; this means there is a change in force at key point 6.
To solve these problems make sure all your key frames start at the beginning of the timeline unless you want the force or other action to be taken after some time. There should be no key frame after the initial one as shown in 7, not even at the end unless you want any specific changes in between or you need to stop the action at certain times without going till the end.

The timeline would be highlighted after calculating the motion if the key frame is active as shown below. If the force is not on, right click the force and click on to make the force active and recalculate.


Motion Analysis
0.1x
0 sec
1 sec
2 sec
Ex. 13.1 (Default<Display State-1
Orientation and Camera View
Lights, Cameras and Scene
Force1
Solid Body Contact1
Gravity
(f) Floor<1> (Default<<Defa
(-) box<1> (Default<<Defaul