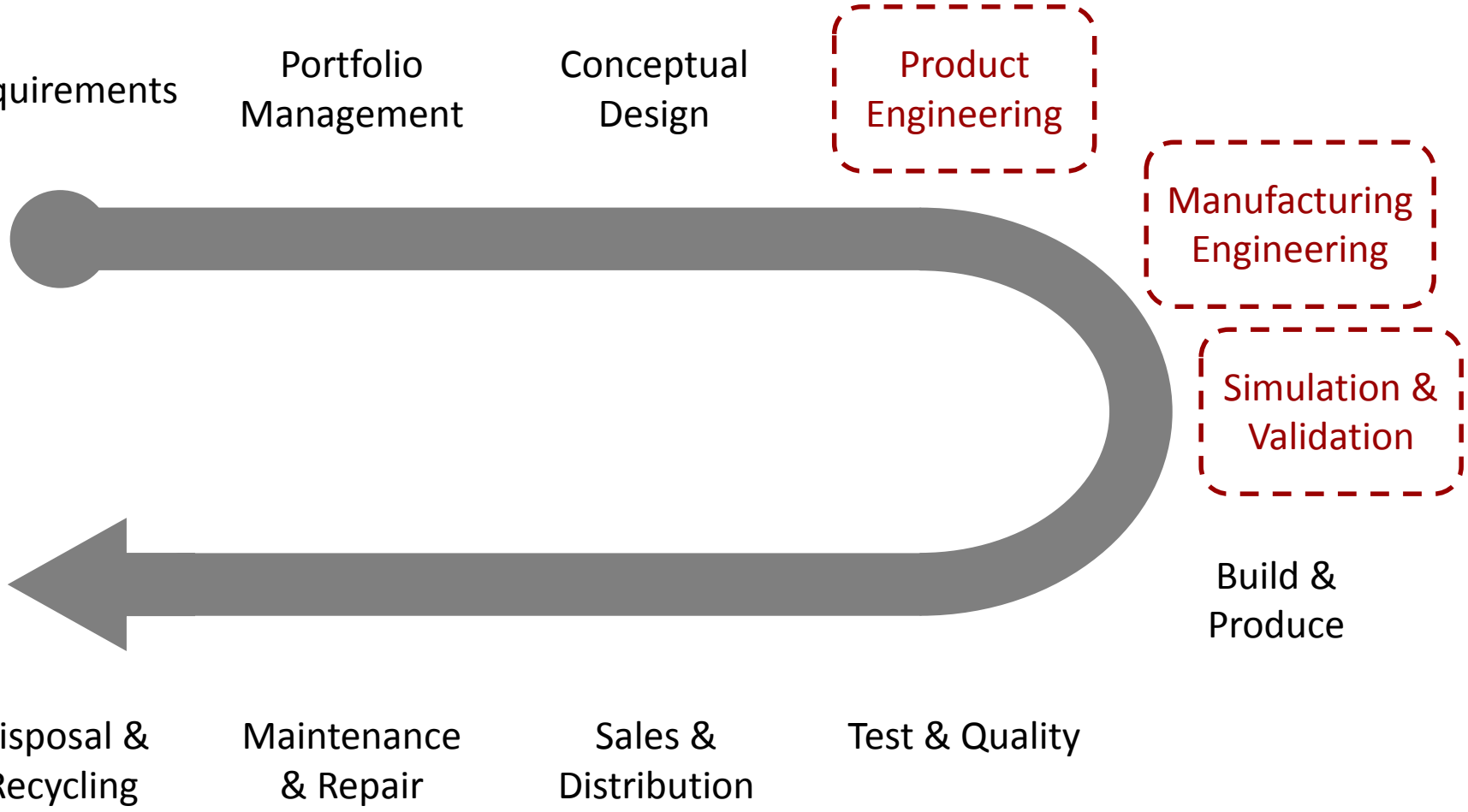
Week 11 - Lecture
Dynamic Motion Simulation

Lecture Topics

- Dynamic Simulation Overview
- Common Use Cases and Terms
- Dynamic Simulation Workflow
- Joint Properties and Types
- Dynamic Simulation Results
- Autodesk Inventor Professional

Product Lifecycle – Week 11

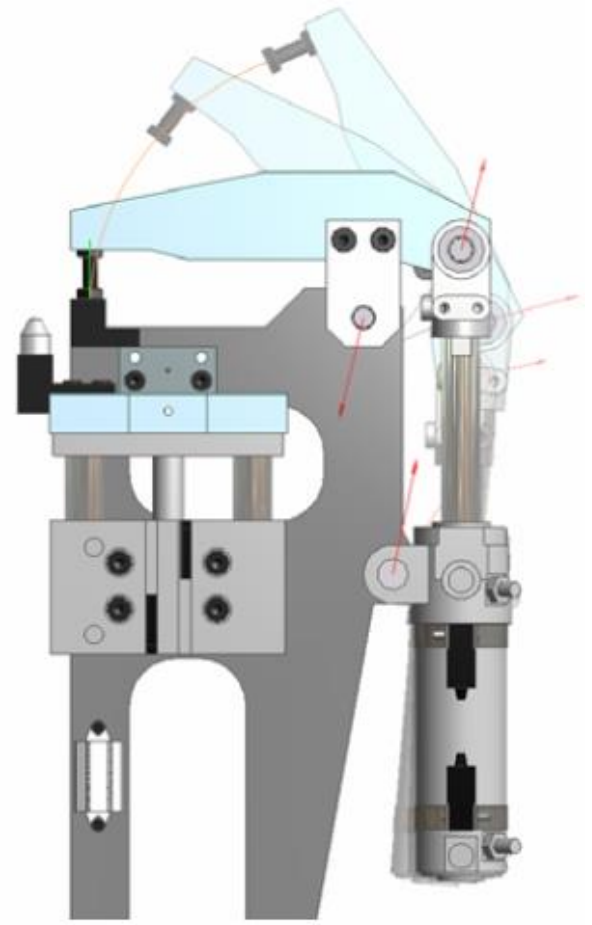


Dynamic Simulation

Creation of motion simulations based on position, velocity, acceleration, and torque as functions of time with external loads on rigid body assembly mechanisms.

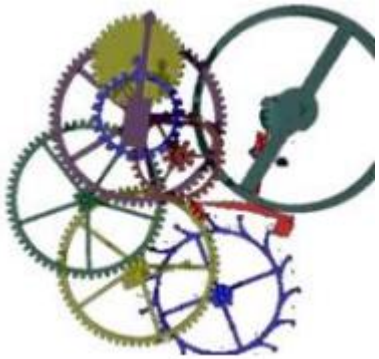
Dynamic Simulation Benefits

- Reduce Physical Prototypes
- Explore Design Options (Early)
- Improve / Optimize Design Performance
- Validate Designs
- Gain Insights for Additional Analysis (FEA)



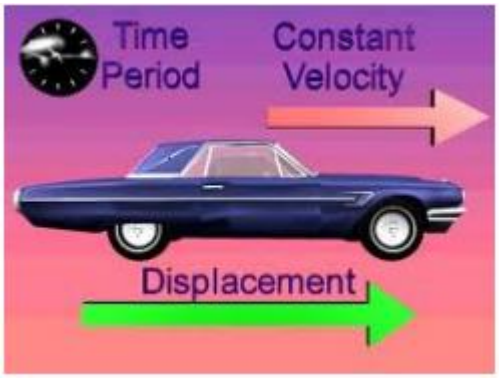
Use Case Examples

- What is the time to complete an operation?
- Will this force be able to lift the object?
- What size motor should we use?
- Will this shape provide the correct motion?
- How much force is required?
- What is the force being applied to this part?



Terms

- Kinematics
  Describes the motion of objects without consideration of forces.
- Dynamic Simulation
  Study of masses and inertial forces acting on a mechanism.
- Rigid Body Dynamics
  Objects that have geometrical properties like center of mass and moments of inertia that characterize motion in six degrees of freedom.



Dynamic Simulation Workflow

The common dynamic simulation workflow is as follows:

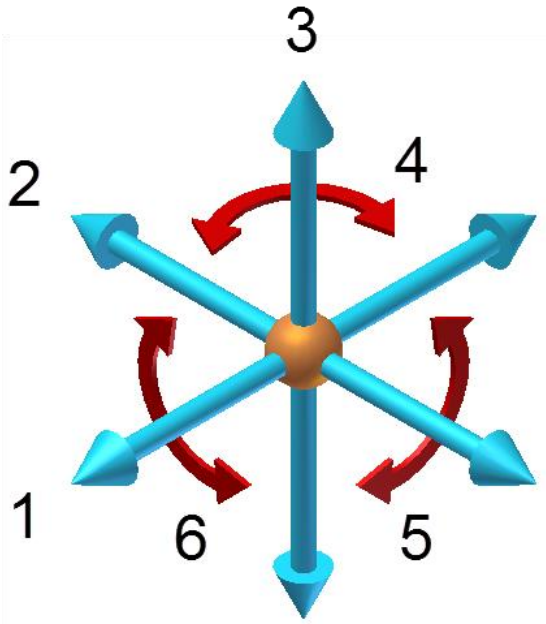
- Step 1 = Preparation
- Step 2 = Creation of Joints
- Step 3 = Add External Forces
- Step 4 = Simulate and Analyze Results

Step 1 - Preparation

- Group components that have no relative motion between them.
  - Manage using assembly structure like subassemblies in main design environment.
  - Manage “welding” components together into groups within just the simulation environment.
- Ensure all components have proper materials properties assigned.

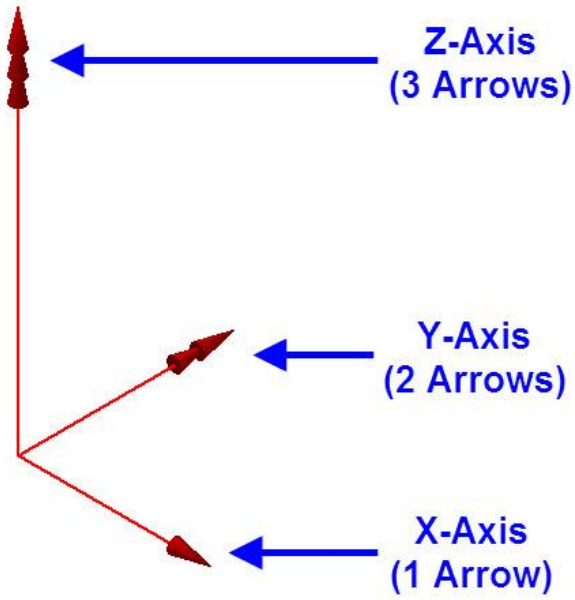
Joint Description

- Joints are links between two rigid components.
- A joint applies force from the first component on the second component.
- Joint coordinate systems are used to define motions and efforts in the joint.

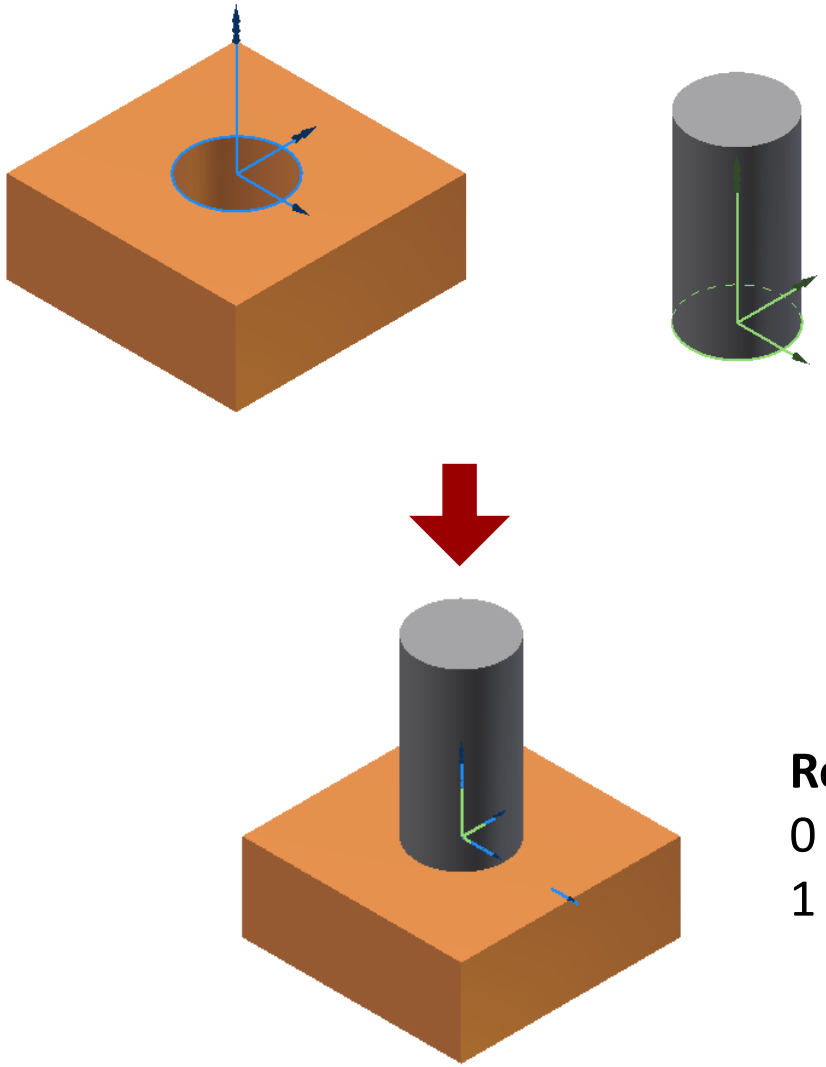


Step 2 - Creating Joints

- Creating joints is the most important element of dynamic simulation.
- Time consuming process.
- Joints control the Degree of Freedom and assign properties like friction and damping.



Standard Mechanical Joint

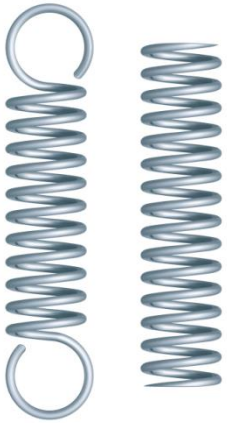


Revolution Joint
0 Translation DOF
1 Rotation DOF

Special Joints

Belts

Gears

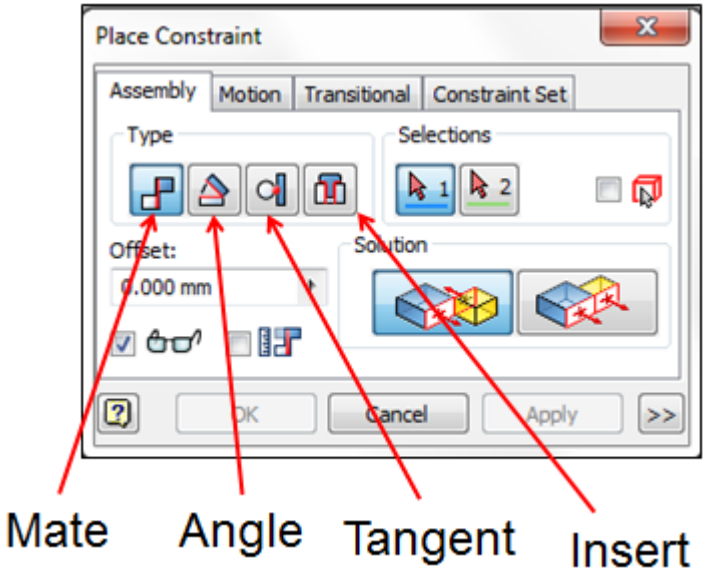


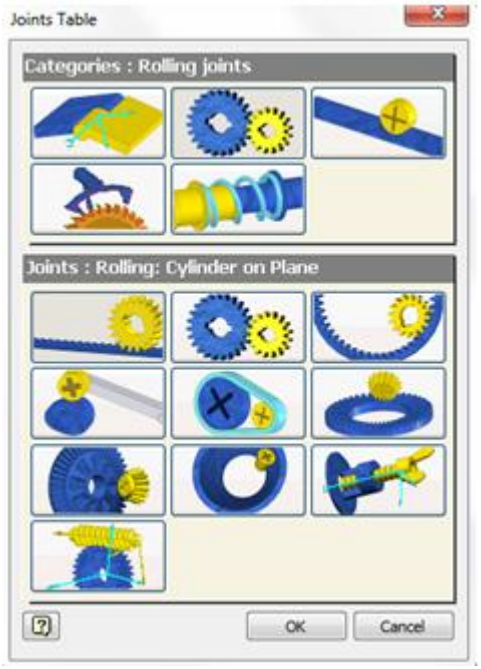
Springs

Contacts

Difference between Constraints and Joints

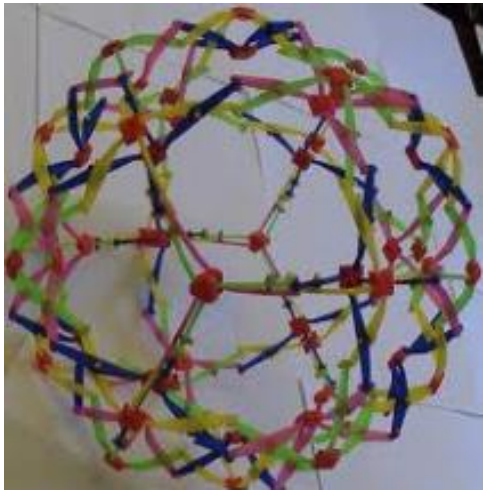
An assembly constraint only respects geometry where as joints contain information like velocity, acceleration, and loads.





Kinematic Chain

Series of components linked by joints. An open chain is attached at only one end. A closed chain, or a loop, is attached to a component at both ends.



Kinematic Model

Group containing at least one kinematic chain beginning from a grounded part. A kinematic model can contain any number of kinematic chains, open or closed.

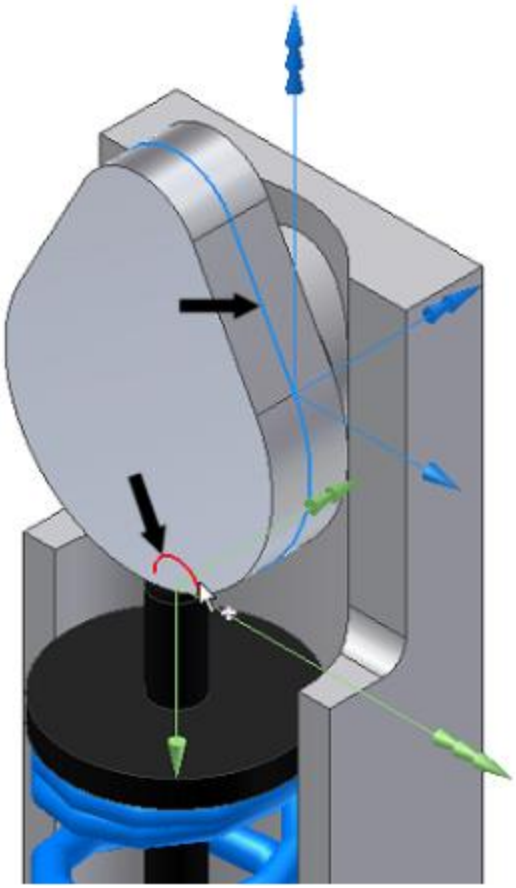
Common Joint Properties

- Restitution

  Indicates the normal velocity of two components after shock. A value of 1 would indicate the object is completely elastic where 0 would be inelastic.

- Friction

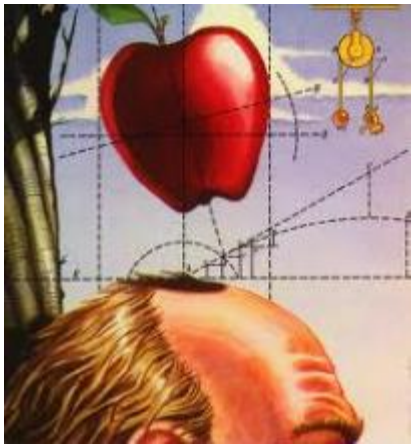
  The coefficient of friction is the ratio that defines the force that resists the motion of one body in contact with another. The most common values are between 0 and 0.2



Step 3 – External Forces

External forces need to be taken into account to ensure all factors are defined that control movement in the simulation. Common external forces are:

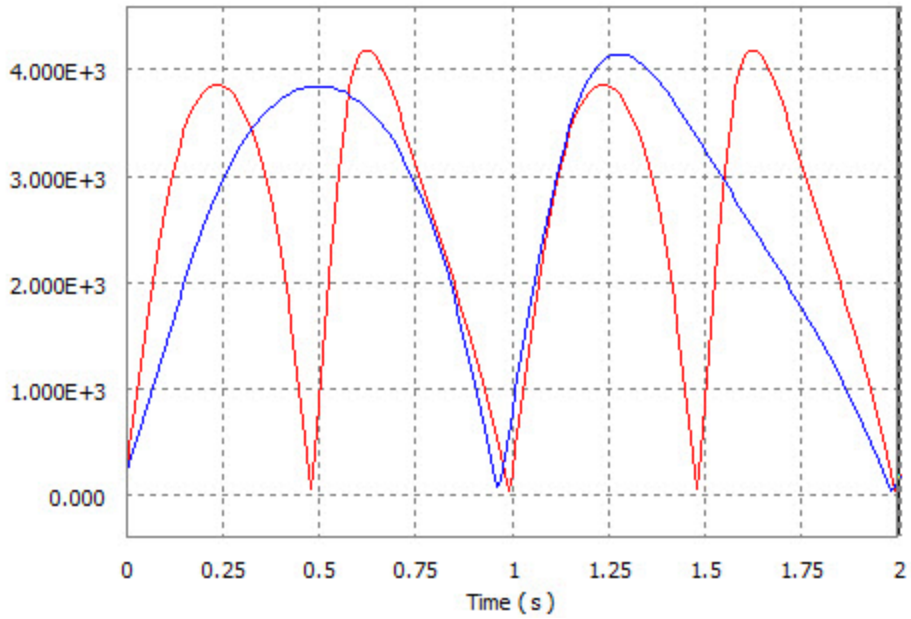
- Gravity
- Force Load
- Torque Load



Step 4 – Review Results

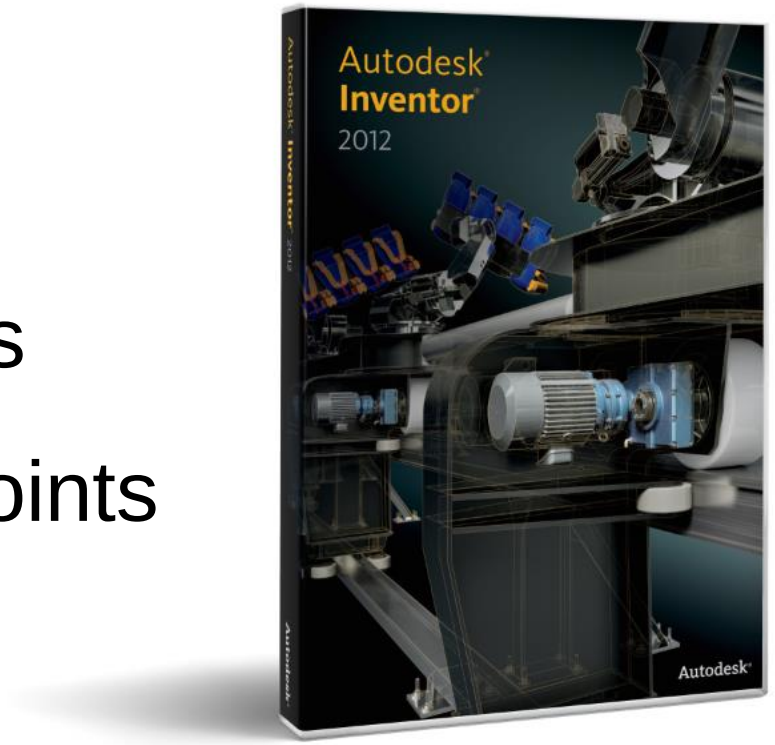
Once the simulation is completed you can analyze and compare results like:

- Reaction forces
- Velocities
- Acceleration
- Moments
- Displacement

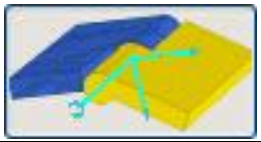
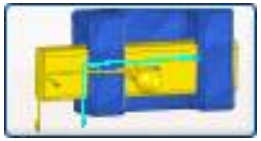
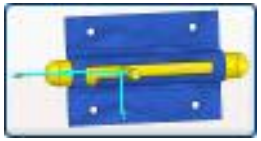
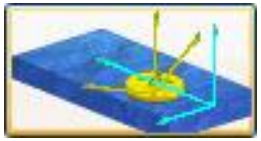


Autodesk Inventor Professional

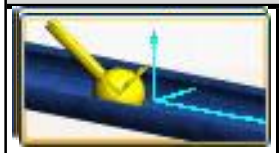
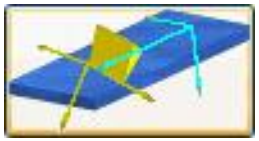
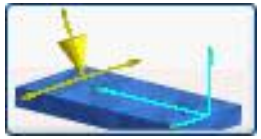
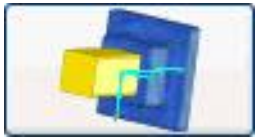
- Dynamic Simulation Environment
- Rigid Body Dynamics
- Linear Dynamic Analysis
- Standard and Special Joints
- Output data for FEA



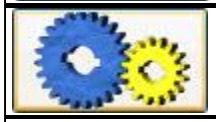
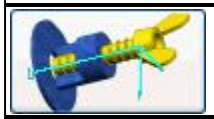
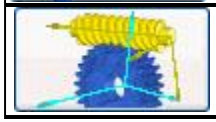
Standard Joints

Dynamic Simulation Joints			D.O.F.
	Revolution	No Translation Rotation around the Z Axis	1
	Prismatic	Translation along the Z Axis No Rotation	1
	Cylindrical	Translation along the Z Axis Rotation around the Z Axis	2
	Spherical	No Translation Rotation along all 3 Axis	3
	Planar	Translation along the X and Z Axis Rotation about the Y Axis	3

Standard Joints

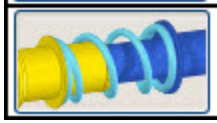
Dynamic Simulation Joints			D.O.F.
	Point - Line	Translation along the Z axis Rotation around all 3 Axis	4
	Line - Plane	Translation along the X and Z Axis Rotation about the Y Axis	3
	Point - Plane	Translation along the X and Z Axis Rotation around all 3 Axis	5
	Spatial	Translation along all 3 Axis Rotation about all 3 Axis	6
	Welding	No Translation No Rotation	0

Rolling Joints

Dynamic Simulation Joints			D.O.F.
	RI Cylinder on Plane	This allows motion between a cylinder and plane	N/A
	RI Cylinder on Cylinder	This allows motion between two primitive cylindrical components in opposite directions.	N/A
	RI Cylinder in Cylinder	This allows motion between a rotating cylinder inside another non rotating cylinder.	N/A
	RI Cylinder Curve	This allows motion between a rotating cylinder and a rotating CAM.	N/A
	Belt	This creates motion of two cylinders with the same speed.	N/A
	RI Cone on Plane	This allows motion between a conical face and a planar face.	N/A
	RI Cone in Cone	This allows motion of a rotating conical component within a stationary conical component.	N/A
	Screw	This is the same as a cylindrical component but allows the user to specify pitch.	N/A
	Worm Gear	This allows motion between a worm gear component and a helical gear component.	N/A

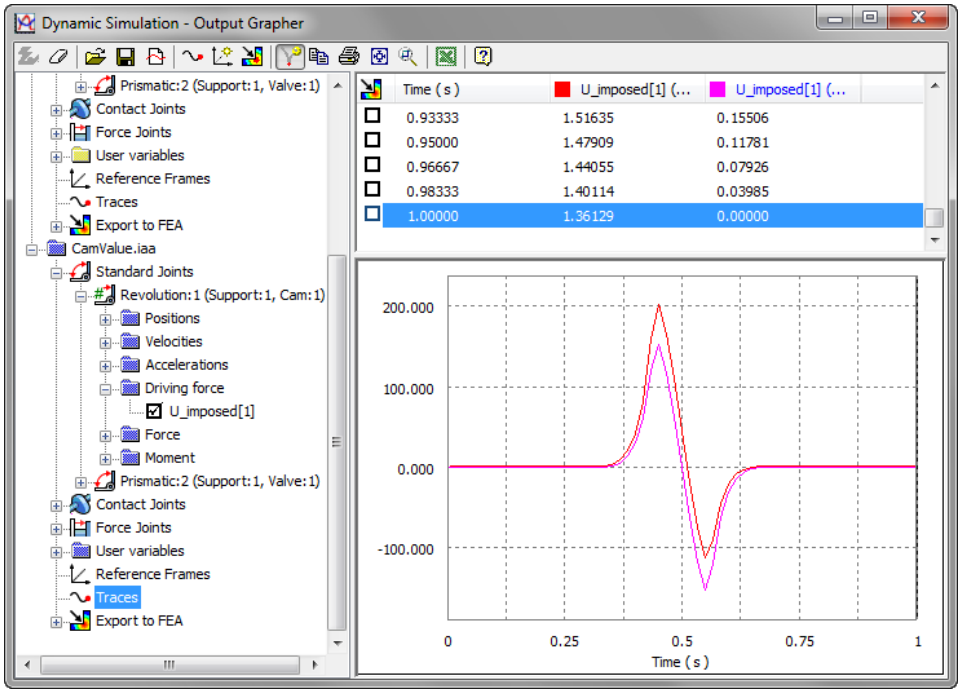
Sliding & Special Joints

Dynamic Simulation Joints			D.O.F.
	SI Cylinder on Plane	This allows sliding between a nonrotating cylinder and plane.	N/A
	SI Cylinder on Cylinder	This allows sliding between two primitive cylindrical components of which one cylinder is nonrotating.	N/A
	SI Cylinder in Cylinder	This allows sliding between a nonrotating cylinder inside another nonrotating cylinder.	N/A
	SI Cylinder Curve	This allows motion between a nonrotating cylinder and a rotating cam.	N/A
	SI Point Curve	This creates motion of a point on one component to stay on a curve.	N/A

Dynamic Simulation Joints			D.O.F.
	2D Contact	This allows motion between the curve of a component and the curve of another component.	N/A
	3D Contact	This allows you to create contact between two components.	N/A
	Spring / Damper / Jack	This allows too create springs, dampers, and jacks.	N/A

Output Grapher

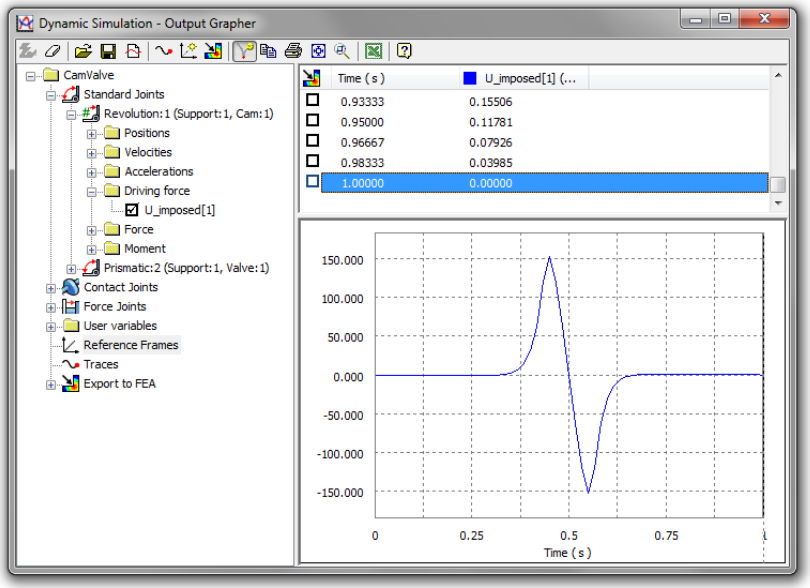
Primary location for reviewing and comparing result data.

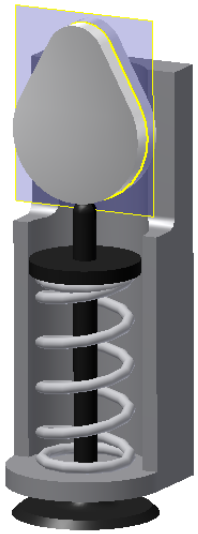


Computer-Cluster Projects (CP11)

Guided Lab Project 1

Guides instructions for completing a dynamic simulation on a cam and value assembly.



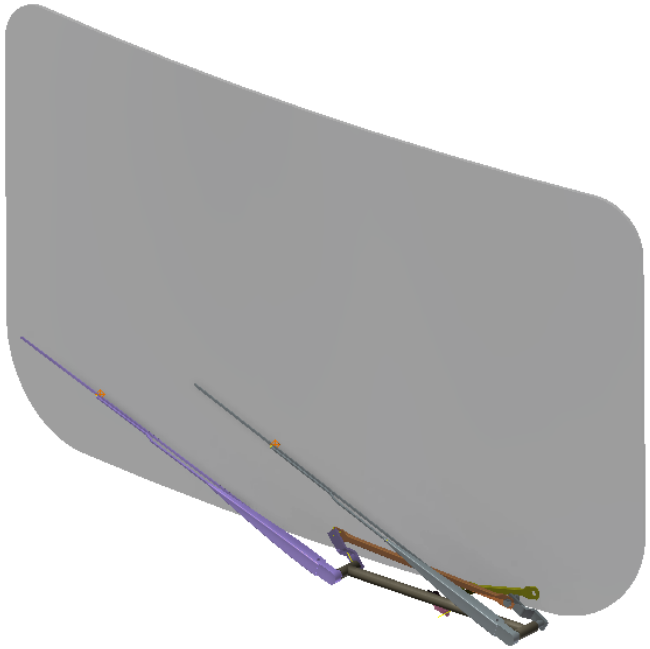


Guided Lab Project 2

Guided instructions for creating mechanical joints in the dynamic simulation.

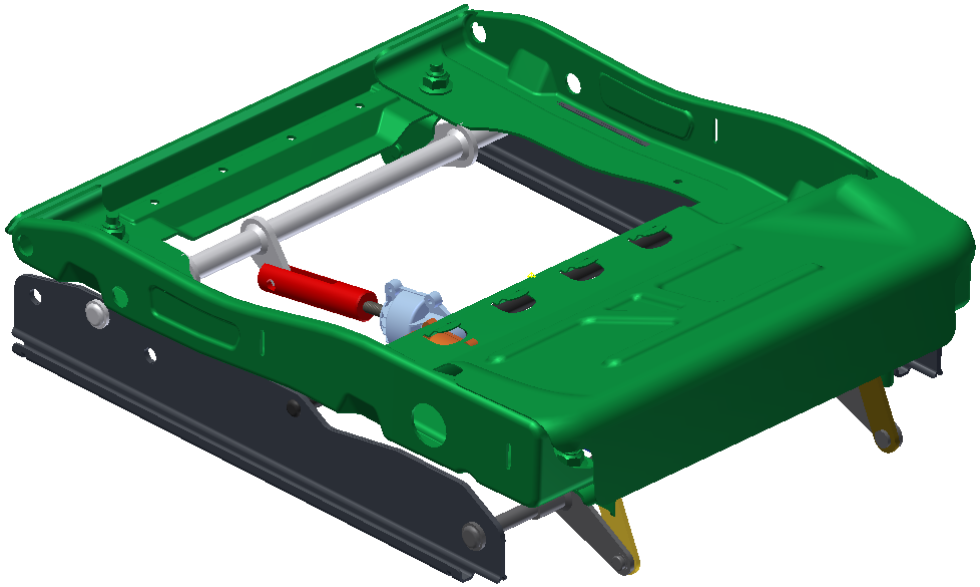
Guided Lab Project 3

Guided instructions for completing a study of the windshield wiper assembly in dynamic simulation.



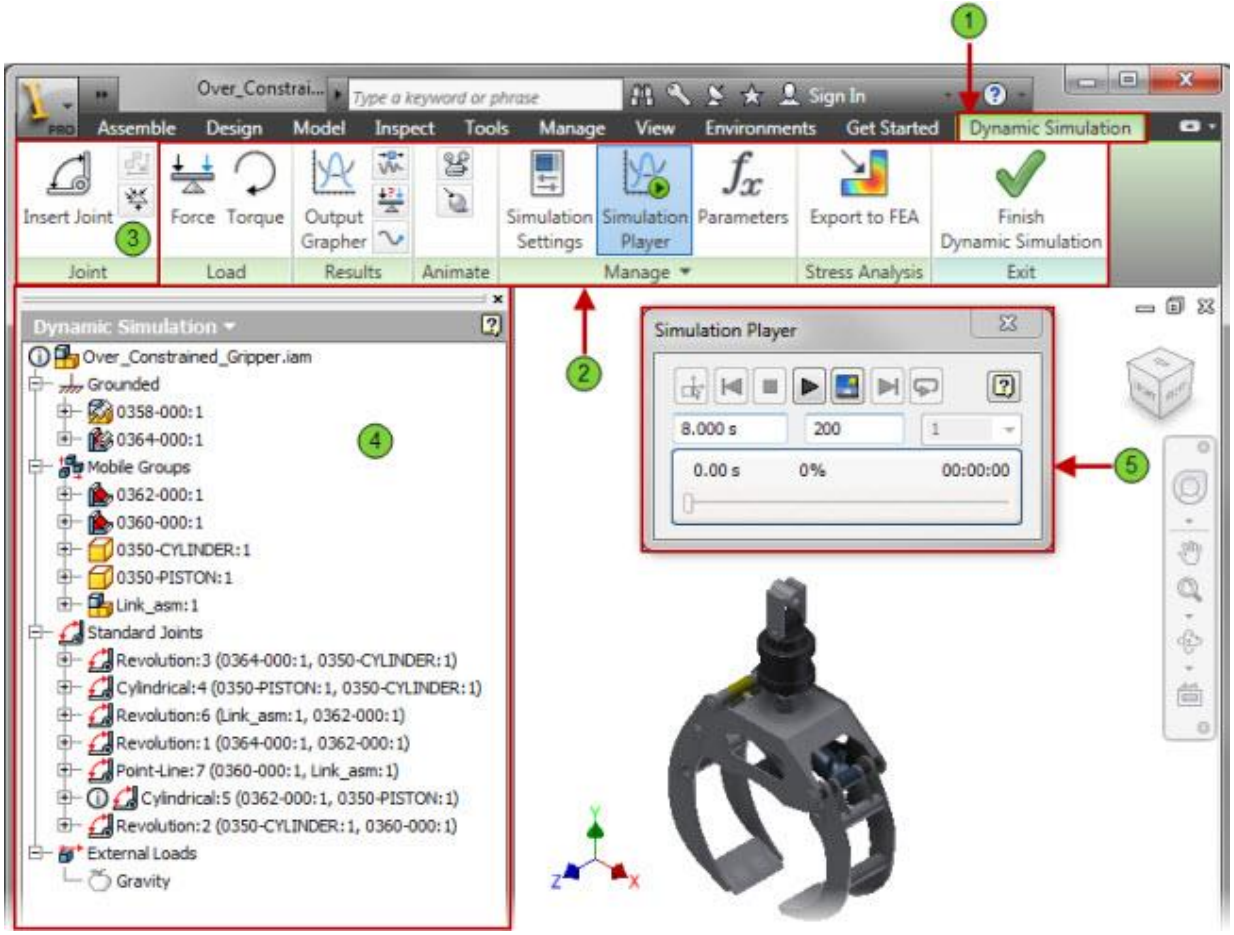
Problem Set Assignment

Simulation the automotive seat lift mechanism to determine changes required to utilize a new motor.



Demo Topics

User Interface

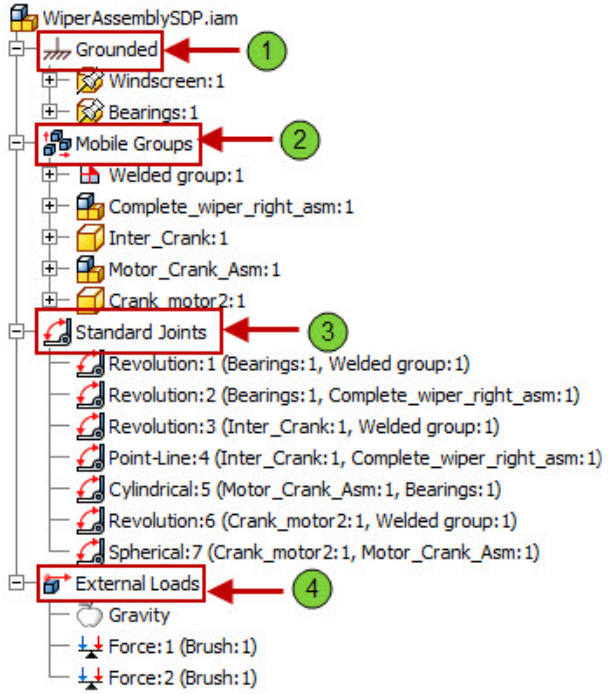


1. **Dynamic Simulation** tab
2. **Dynamic Simulation** panels
3. **Dynamic Simulation** tool
4. **Dynamic Simulation** browser
5. **Simulation Player**

Dynamic Simulation Panels

1. Tools to create joints, convert constraints, and check the status of the mechanism.
2. Tools to apply force and torque.
3. Tools used to display results and traces.
4. Tools used to create animations.
5. Tools used to manage simulation settings and parameters.
6. Tool used to export data to FEA.
7. Tool used to exit Dynamic Simulation.

Dynamic Simulation Browser



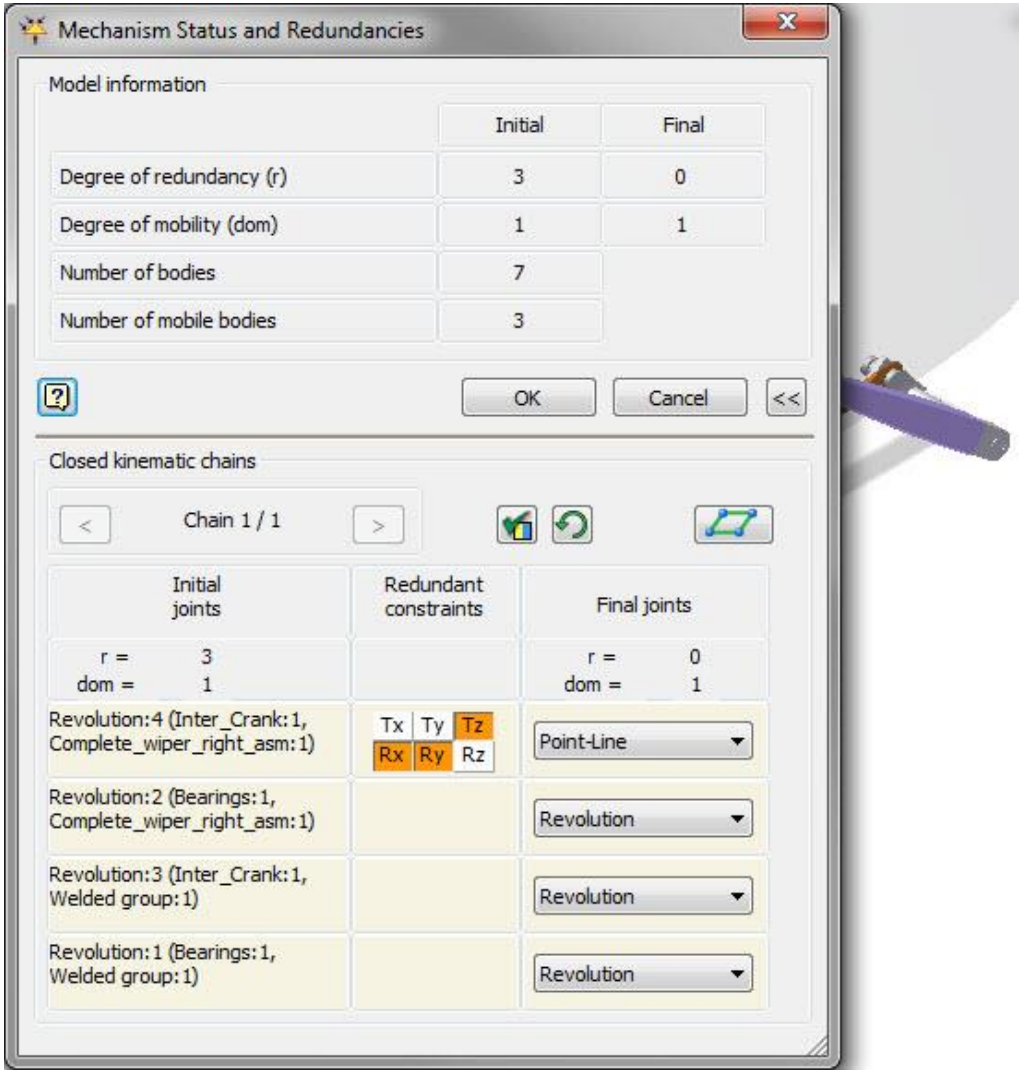
1. Rigid components linked to ground on one end and all parts not yet used by the dynamic definition of the mechanism.

2. Subassemblies, weldments, and parts that are not grounded.

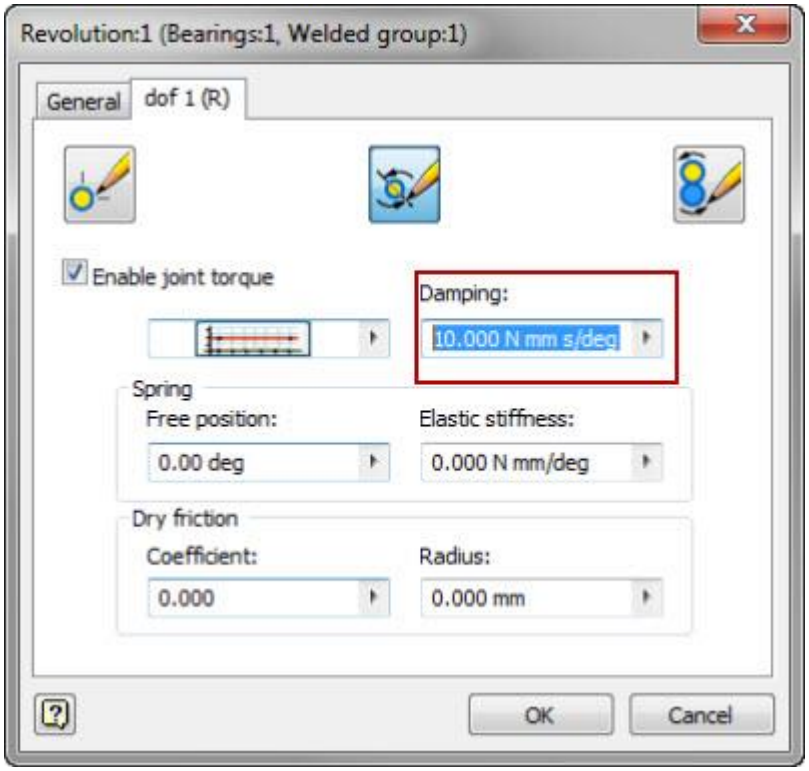
3. Joints created automatically or manually.

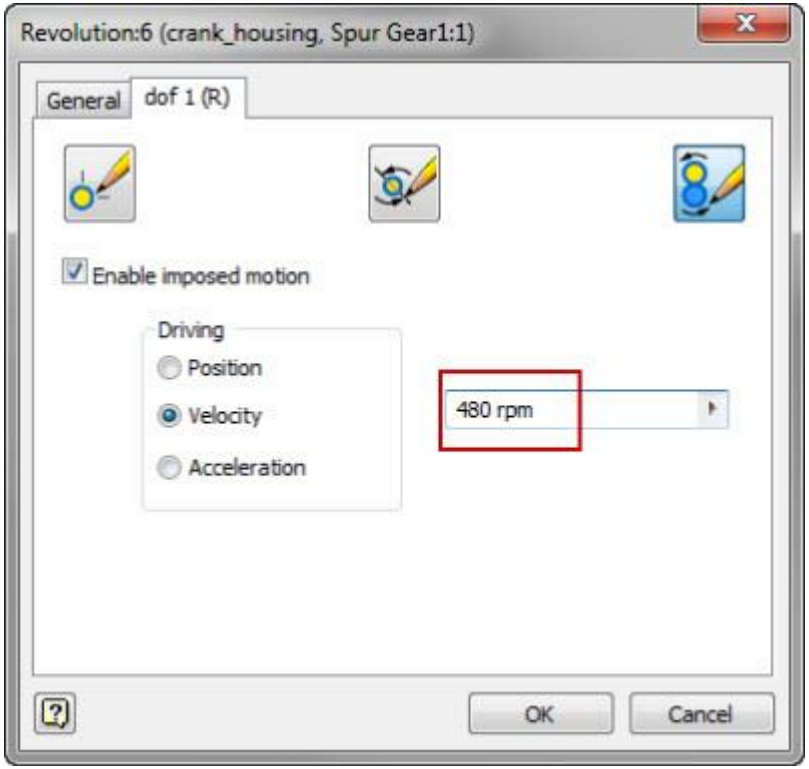
4. Loads such as gravity, individual forces, or individual torque.

Joint Redundancies

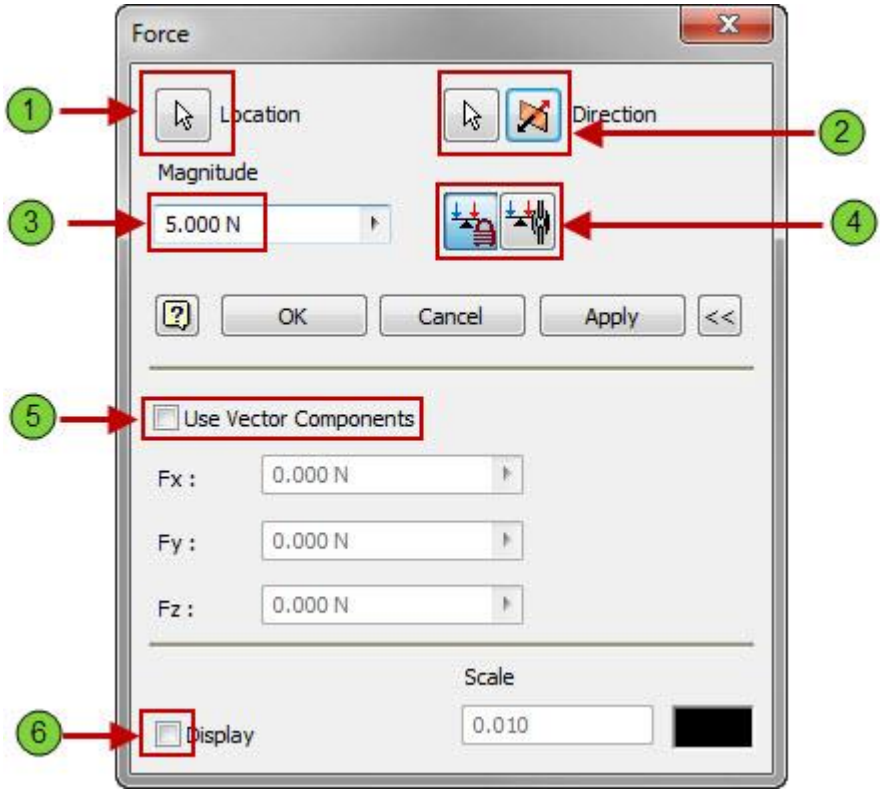


Joint Properties



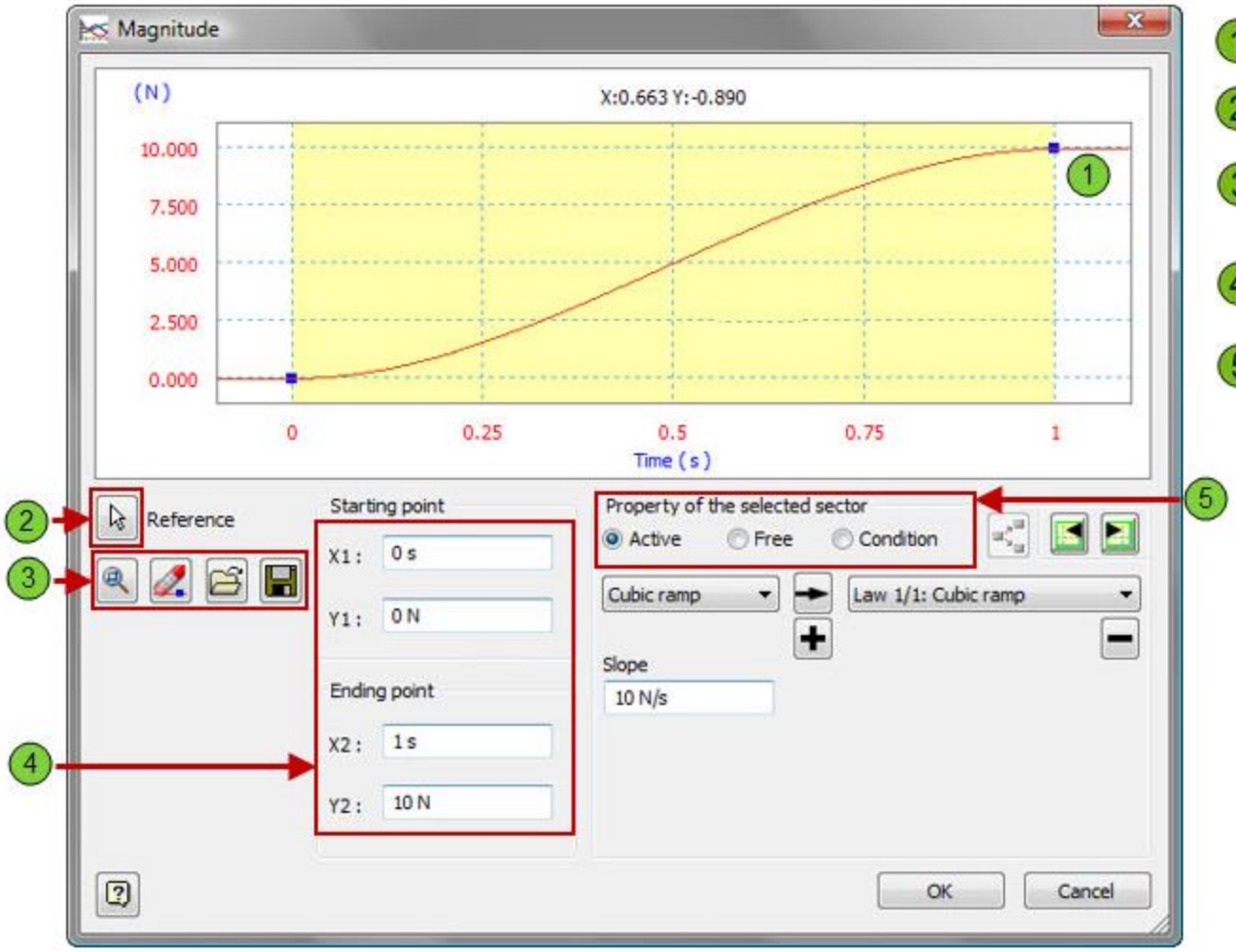


External Forces



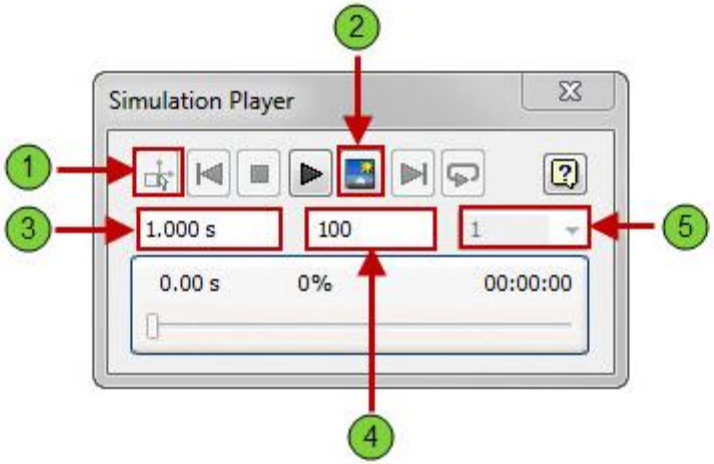
1. Force **Location**
2. Load **Direction**
3. **Magnitude** of the Load
4. **Fixed / Associative** Load Direction
5. **Vector** Based Load Direction
6. **Display** Load Glyph

Input Grapher



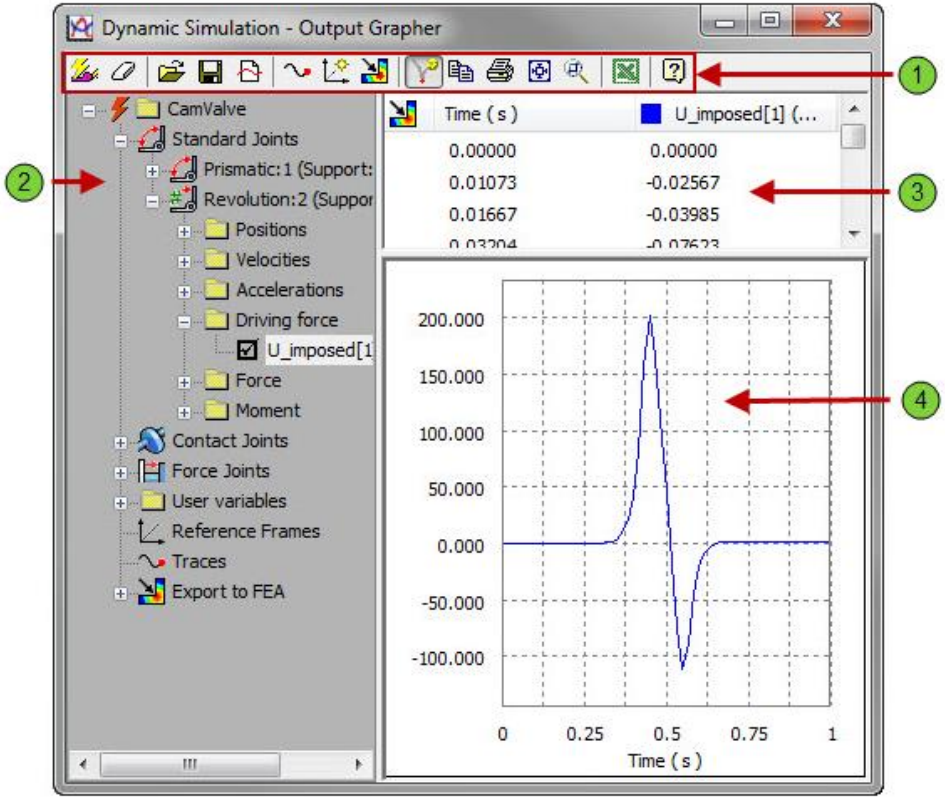
1. Graph Region
2. Reference button
3. Command Buttons
4. Starting Point
   End Point
5. Property of the Select Sector

Simulation Player



1. Return to the construction mode.
2. Deactivates the screen refresh.
3. Sets the time for the simulation to run.
4. Displays the number of images to save during the simulation.
5. Displays the number of frames to display.

Output Grapher



1. **Toolbar –** Commonly used commands.
2. **Browser –** Displays all of the available simulation variables.
3. **Time Steps pane –** Displays the output results at each step.
4. **Graphics Window –** Displays curves of values for selected variables. You can view results in the Graphics Window during or after a simulation.