# Working Model Tutorial for Slider Crank

## 1) Start Working Model 2D

#### 2) Set display and units

Select <u>View</u> then <u>Workspace</u> Check the X X Aves and Coordinates how

Check the <u>X,Y Axes</u> and <u>Coordinates</u> boxes and then select <u>Close</u> You may also select <u>Grid Lines</u> and <u>Rulers</u> if you wish

Workspace		
Navigation	Toolbars	Close
📝 Coordinates	🔽 Standard	Liose
Rulers	📝 Edit	
Grid Lines	📝 Run Control	
📝 X,Y Axes	📝 Join/Split	
	📝 Body	
Scrolling	📝 Points	
🔽 Tape player controls	📝 Joints	
📝 Scroll bars	🔽 Cnstr	
🗹 Status bar	Simple	

Select <u>View</u> then <u>Numbers and Units</u> then <u>More Choices</u> Select <u>Distance</u> in <u>Millimeters</u> Select <u>Rotation</u> in <u>Radians</u> and then select <u>OK</u>

Numbers and Units				×
Unit System: Custom ▼	Numbers Fixed Point Floating Point Auto	6	Digits	OK Cancel Fewer Choices
Distance Millimeters 🔹 Mass Kilograms 👻				▼ N
Time Seconds 🔻	s F	ower (	Watts	•w
Charge Coulombs 🔻	C Frequ	lency (	(none)	-
Rotation Radians 🔻	rad Ve	elocity (	(none)	•
Pot. Volts	V Rot. Ve	elocity (	(none) ·	•

#### Select <u>View</u> then <u>View Size</u> Set <u>Window width</u> to 100 then select <u>OK</u>

View Size			×
Objects on screen are	4.497917	times actual size	ОК
Window width	100.000000	mm	Cancel

## 3) Save this example

Select File then Save As and choose a suitable folder and filename and then select Save

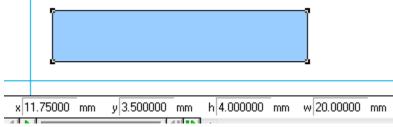
## **REMEMBER TO SAVE YOUR WORK OFTEN!**

## 4) Draw a link and add points to it

Select the <u>Rectangle</u> drawing tool from the tool bar on the left and draw a rectangle



You may use the H and W indicator boxes at the bottom tool bar to resize



Select the round <u>Point Element</u> drawing tool from the tool bar on the left Position the cursor over an edge of the link and **WAIT** for a small X to snap onto that edge Left-click to attach the point to the link

Place a second round point on the link





#### 5) Label the link and points

Left-click on the link to highlight it and select <u>Window</u> then <u>Appearance</u> Remove checks on <u>Track center of mass</u> and <u>Track outline</u> box Check <u>Show</u>, <u>Show name</u> and <u>Show center of mass</u> boxes Left-click on the box containing "Rectangle" and enter the name "Crank"

Appear	ance		×
Fill:	Color Pattern	× Body[1] - Crank ▼	✓ Show ✓ Show name
Frame:		Crank	Show center of mass
Fill R:	0.600000	Track connect	Show charge
G:	0.800000	🔲 Track outline	Show circle orientation
B:	1.000000		

Left-click on one point on the link and select <u>Window</u> then <u>Appearance</u> Remove the check on the <u>Track center of mass</u> box

Check the <u>Show name</u> box

Left-click on the box containing "Point" and type the name "A"

Appearance		×
	Point[2] - A     A     A     Track center of mass     Track connect	✓ Show ✓ Show name

Repeat to name the other point B



#### 6) Create a revolute joint connected to ground

Select the round <u>Point element</u> drawing tool from the tool bar on the left Position the cursor and left-click to attach a ground pin

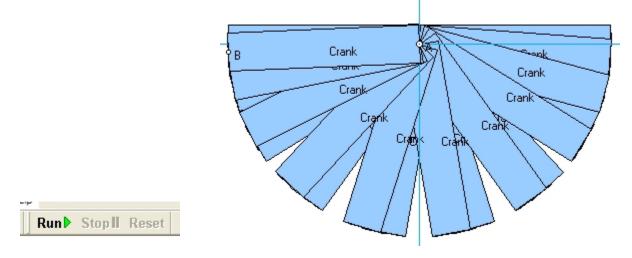


Left-click on the ground pin to highlight it if necessary

Hold down the Shift Key and left-click on point A on the Crank to highlight it also Select the Join button from the tool bar on the left to create a revolute joint



You should be able to left-click and drag the link to move it around Animate your pendulum by selecting <u>Run</u> and then later <u>Stop</u> from the toolbar at the top Select <u>World</u> then <u>Erase Track</u> (Ctrl+E) to clean the screen if needed



## 7) Create a revolute joint connected to another link

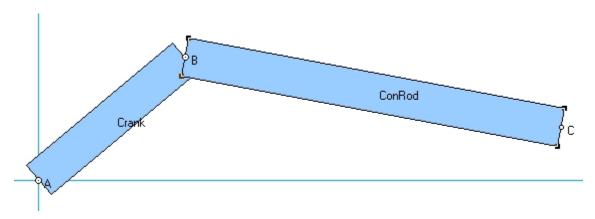
Repeat steps 4) and 5) to create "ConRod" with round points B and C attached to it



Left-click on point B on Crank to highlight it

Hold down the Shift Key and left-click on point B on the ConRod to highlight it also Select the Join button from the tool bar on the left to create a revolute joint

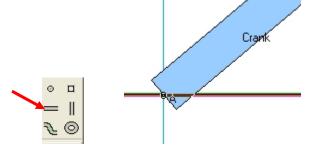




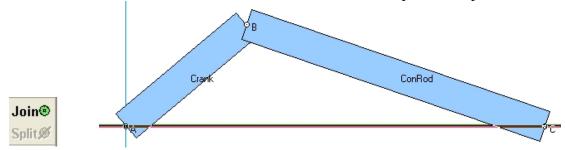
You should be able to left-click and drag the links to move them around

## 8) Create a pin-in-slot joint connected to ground

Select the <u>horizontal Slot element</u> drawing tool from the tool bar on the left Position the cursor and left-click to attach a slot to ground



Left-click on the slot to highlight it if necessary Hold down the Shift Key and left-click on point C on the ConRod to highlight it also Select the Join button from the tool bar on the left to create a pin-in-slot joint



You should be able to left-click and drag the links to move them around

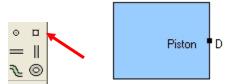


## 9) Create a prismatic joint

Repeat step 4) to create a small block "Piston"

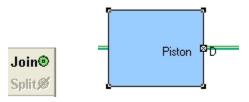


Select the <u>Square Point element</u> drawing tool from the tool bar on the left Position the cursor over an edge of the Piston and **WAIT** for a small X to snap onto that edge Left-click to attach the point to the Piston and name it D



Left-click on the slot to highlight it

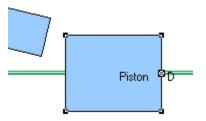
Hold down the Shift Key and left-click on square point D on the Piston to highlight it also Select the Join button from the tool bar on the left to create a prismatic joint



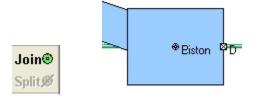
You should be able to left-click and drag the link to slide it

#### 10) Create a slider crank

Left-click on point C on the ConRod to highlight it and press the Delete Key to remove point C Left-click and drag the ConRod away from the slot



Add a new round point C to the end of the ConRod Add a new round point C to the middle of the Piston Highlight the points and use the <u>Join</u> button to create a revolute joint



You should be able to left-click and drag the links to move them around

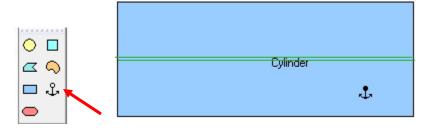
## 11) Create a slot connected to a link

Repeat steps 4) and 5) to create a large block "Cylinder" Select the <u>horizontal Slot element</u> drawing tool from the tool bar on the left Position the cursor over the Cylinder and left-click to attach a slot to the Cylinder



Select the <u>Anchor</u> tool from the tool bar on the left

Position the cursor over the Cylinder and left-click to connect the Cylinder to ground



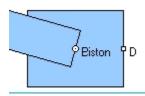
Left-click on square point D to highlight it and press the Delete Key to remove point D Left-click and drag the Piston away from the ground slot

Left-click on the ground slot and press the Delete Key to remove it

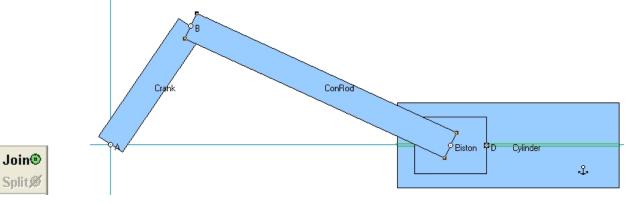
Add a new square point D to the Piston

Left- click on the Piston and select Object then Move to Front

Left- click on the ConRod and select Object then Move to Front



Move the slot in the cylinder where the ground slot had been Left-click on the slot attached to the Cylinder to highlight it if necessary Hold down the Shift Key and left-click on point D on the Piston to highlight it also Select the Join button from the tool bar on the left to create a prismatic joint



You should be able to left-click and drag the links to move them around The Cylinder should not move

## 12) Collision

Depending on how you designed your Piston, the ConRod may collide with your Cylinder You can ignore or enforce collision between objects in two ways

Global setting

Select World then Preferences and choose if you want all objects to collide or not collide

Preferences	
Edit objects as	Collision options
<ul> <li>Outlines (faster)</li> </ul>	Objects collide by default
Objects	Objects do not collide by default
Allow velocity vector dragging	
Calculate initial conditions autor	natically
Prevent editing except at initial	conditions
Change cursor to stop sign duri	ng Run
Loop when tape player is full	
V Automatic point equations on O	bject Snap
📝 Prevent model from running fast	er than real-time
Save current settings	Cancel OK

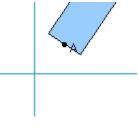
Pairs of objects

Left-click on one object and then hold down the Shift Key and left-click on another object Then select <u>Object</u> and <u>Collide</u> or select <u>Object</u> and <u>Do Not Collide</u>

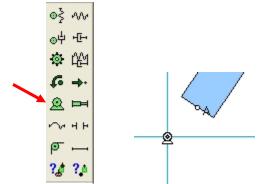
<u>O</u> b	ject <u>I</u>	<u>D</u> efine	<u>M</u> easure	<u>S</u> cript	V
۲	<u>J</u> oin		C	trl+F1	ł
0.10	<u>S</u> plit		C	trl+F2	H
	Move	To <u>F</u> ron	t	Ctrl+F	L
	Send 1	Γο <u>B</u> ack	(	Ctrl+G	L
ġģ	<u>C</u> ollid	e			L
00	Do <u>N</u> o	t Collid	e		l
A	<u>F</u> ont				l
<b>4</b> 6	Vary tl	he Soun	d		l
₿	Vary tl	he Feel			l
	Attack	n <u>P</u> icture	2		l
	<u>A</u> ttach	n To Boo	ły	Ctrl+B	L
	Conve	ert <u>O</u> bjeo	ts	•	I

## 13) Add a motor

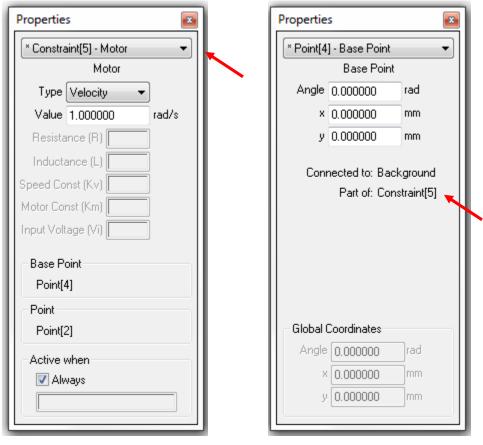
Left-click on point A on the Crank to highlight it and press the Delete Key to remove point A Move the end of the crank away from the origin and add a new round point A to the Crank



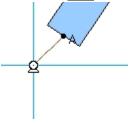
Select the <u>Motor</u> drawing tool Position the icon and left-click to attach the motor to ground



Left-click on the motor to highlight it Select <u>Split</u> from the tool bar on the left Select <u>Window</u> then <u>Properties</u> to see the names for the Base Point and the Motor in the <u>Properties</u> window



Left-click on the CENTER of the motor and drag the point icon onto point A on the Crank Select the Join button from the tool bar on the left



Double left-click on the motor to show the <u>Properties</u> pop-up Use <u>Type Velocity</u> to create a speed control motor A constant positive value causes a constant CCW rotation speed

Propertie	s	<b>×</b>
× Constra	aint[5] - Motor	-
	Motor	
Туре	Velocity	• •
Value	1.000000	rad/s
Resista	ince (R)	
Inducta	ance (L)	
Speed Co	nst (Kv)	
Motor Co	nst (Km)	
Input Volt	age (Vi)	
Base P	oint	
Point[4	4]	
Point		
Point[2	2]	
Active	when	
🔽 Alv	vays	

Animate your slider crank by selecting <u>Run</u> and then later <u>Stop</u> from the toolbar at the top Select <u>World</u> then <u>Erase Track</u> (Ctrl+E) to clean the screen if needed

Use Type Rotation to create a position control motor

You may enter a formula in the value window to vary position as a function of time The formula "1.57\*sin(3.14\*t)" will produce ±90 degrees of rotation at 0.5 Hz (2 second period).

Use <u>Type Torque</u> to create a torque control motor

A constant positive value causes a constant CCW torque

Alternately you may enter a formula in the value window to vary torque as a function of time

## 14) Changing animation speed and integrator error

## Select World then Accuracy

Smaller values for the upper box under <u>Animation Step</u> provide fewer animation steps

Simulation Accur	racy		x
○ Fast	Animation Step	Integrator Error	ОК
<ul> <li>Accurate</li> <li>Custom</li> </ul>	<ul> <li>0.050000</li> <li>20.000000</li> </ul>	10.000000 mm	Cancel More Choices

For very fast motion, default settings may cause joints to drift apart The following settings are a good place to start when making adjustments

Select <u>World</u> then <u>Accuracy</u> Manually set <u>Animation Step</u> to 0.001 sec Select the <u>Integrator Error</u> radio button for <u>Automatic</u>

Then select More Choices

Select the <u>Integrator</u> radio button for <u>Kutta-Merson (accurate)</u> Select the <u>Integration Step</u> radio button for <u>Variable</u> Select <u>Overlap Error</u> and <u>Assembly Error</u> and <u>Significant digits</u> radio buttons for <u>Automatic</u>

Simulation Accura	cy			×
<ul> <li>Fast</li> <li>Accurate</li> <li>Custom</li> </ul>	Animation Step Automatic 0.05000 20.00000		Integrator Error     Automatic     0.078142 mm	OK Cancel Fewer Choices
Integrator C Euler (approxi Kutta-Merson		⊂Integrati ⊚ Fixeo ⊚ Varia	Integration step: 0.05	500I <sup>s</sup>
Overlap Error:	<ul> <li>Automatic</li> <li>0.078142</li> </ul>	mm	Warnings	ion
Assembly Error:	<ul> <li>Automatic</li> <li>0.007814</li> </ul>	mm	<ul> <li>Initial body overlap</li> <li>Redundant constra</li> </ul>	
Significant digits	◎ 7		Inconsistent constr	aints
	Dptional frict	ion model		

## 15) Modify link inertial properties

Left-click on the ConRod to highlight it and select <u>Window</u> then <u>Appearance</u> Check the <u>Show center of mass</u> box

Select <u>Window</u> then <u>Geometry</u>

Select the radio button for <u>COM x-offset</u> to change the centroid location

Geometry			
Body[1] - Co	onRod	-	
Area COM	ConRod 160.000000	mm^2	
Auto x-offset	-10.000000	mm 🚽	
	0.000000	mm	
Height	4.000000	mm	
Width	40.000000	mm	

Select Window then Properties

You may change the mass and mass moment of inertia Note: WM assumes all objects are 1 unit thick

## 16) Create a polygonal link

Select the <u>Polygon</u> drawing tool from the tool bar on the left Left-click for the first vertex Move the cursor and left-click to place more vertices Double left-click to complete the <u>Polygon</u>

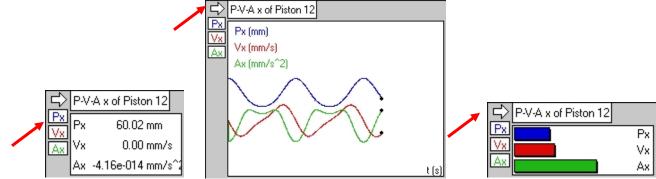
Left-click on the polygonal object to highlight it Select <u>Window</u> then <u>Geometry</u> Edit the table at the bottom of the Geometry pop-up to resize your object You may edit in World coordinates or Shape coordinates You may Insert new vertices or Delete current vertices

## 17) Displaying and exporting numerical data

Left-click on the Piston to highlight it and select <u>Measure</u> then <u>P-V-A</u> then <u>X</u>

Select  $\underline{Run}$  and then later  $\underline{Stop}$  from the toolbar at the top

Different output formats for the <u>Measure</u> window may be selected with the hollow arrow You may have several <u>Measure</u> windows for different variables open at the same time To remove a <u>Measure</u> window, left-click on it to select and press the Delete Key



Select <u>File</u> then <u>Export</u> and choose a suitable folder and filename Select <u>Export type</u> Meter Data (\*.dta)

Select Export to save meter data from your most recent run

\*.dta files contain tab-delimited text and may be opened with Notepad, Word or Excel

₩ Export			×
Export to:	🔋 wm 👻	G 🤌 📂 🛄 -	
0	Name	Date modified	Туре
Recent Places	n02_sc_04.dta	8/26/2014 2:57 PM	DTA File
Desktop			
Libraries			
(Normality Computer C			
Network	< III		+
	Export filename: n02_sc_04.dta	-	Export
	Export type: Meter Data (*.dta)	▼	Cancel
Frame First: 0 Last: 323		otions	

## 18) Exporting animation

Select <u>File</u> then <u>Export</u> and choose a suitable folder and filename Select <u>Export type</u> Video for Windows (\*.avi)

Select Export to save an AVI animation of your most recent run

You may also control the number of frames that are exported

Note: Exporting \*.avi files may cause problems with exporting \*.dta files in future runs

<mark>₩</mark> Export					x
Export to:	\mu wm		- 3 🕫	► 🔝 🏷	
Recent Places	i n02_sc_04.avi	i			
Desktop					
Libraries					
Computer					
(interview of the second secon					
	Export filename:	n02_sc_04.avi		•	Export
	Export type:	Video for Windows (*.avi)		•	Cancel
Frame First: 0 Last: 323			Options		