# Mechanism Analysis in Pro/E



MAE 4344 Mechanical & Aerospace Engineering University of Texas at Arlington Mukund Narasimhan & Kent L Lawrence

# Link Specs

- Each link is 0.5 inch thick and 1.0 inch wide.
- The pin holes are 0.5 inch in diameter, and link lengths are between pin hole centers.
- The material for each is steel.

# Joint definitions



# Motion

- The 5 inch input link rotates at a constant angular speed of 1800 rpm = 10,800 deg/sec in a CCW sense.
- Find the connection forces at each joint for one revolution of the mechanism.

#### **GROUND BLOCK**



#### Change units from Inch Lbm Sec to Inch Lbf Sec for ALL parts.



## LINK 1



## LINK 2



## LINK 3

Pro/ENGINEER Educational Edition (I	for educational use only)
<u>Eile E</u> dit <u>V</u> iew <u>I</u> nsert <u>A</u> nalysis I <u>n</u> fo	Applications Tools ANSYS 9.0 Window Help
) 🗅 📂 🖬 🖨 🖓 🖓 🗠	◇◣◨◨╫═▾┃◙ਆਲ਼९९┓◗ぴ◱┃@ㅎ
□ 🛴 🔏 💥 🖌 🕺	
	E File Open
	Look In 🗋 Dinesh 🔽 🗈 🖻 🗁 🖄 🗮 🏹
3	sm0001.asm
	block.prt
>	
	☐ link3.prt
	🚺 setup_links.asm
>	
2	
	Name block at
	Open         Open Rep         Cancel         Preview >>>
efine Materials	
n all Danta	File > Open > Select link1 prt
i all Parts	

LINK1 (Active) - Pro/ENGINEER Educational Edition (for educational use only)	-OX	Menu Manager
Eile Edit View Insert Analysis Info Applications Tools ANSYS 9.0 Window Help		- PART SETUP
Ele Edit yew Insert Analysis Info Agplications I pols ANSYS9.0 Window Help		<ul> <li>▶ PART SETUP</li> <li>▶ Material</li> <li>Accuracy</li> <li>Units</li> <li>Name</li> <li>Notes</li> <li>Symbol</li> <li>Mass Props</li> <li>Dim Bound</li> <li>Dimension</li> <li>Ref Dim</li> <li>Shrinkage</li> <li>Geom Tol</li> <li>Surf Finish</li> <li>Grid</li> <li>Tol Setup</li> <li>Interchange</li> <li>Ref Control</li> <li>Comp Interface</li> <li>Designate</li> <li>Flexibility</li> <li>Done</li> <li>▼ MATRL MGT</li> <li>Define</li> <li>Delete</li> <li>Edit</li> <li>Show</li> <li>Write</li> <li>Assign</li> <li>Unassign</li> </ul>
<ul> <li>Coordinate Systems will not be displayed.</li> <li>Enter material name steel</li> <li>Base window cannot be closed.</li> <li>Base window cannot be closed.</li> <li>Enter material name Steel</li> </ul>	- 	*

Edit > Setup > Material > Define > (Enter material name) Steel > Accept

=   <b>A</b>
=   <b>A</b>

A notepad opens up > Enter MASS\_DENSITY = 0.7331E-03 > File > Save as > Steel.mat > Exit (First toggle on 'all files' not 'TXT'.)



#### Assign > From Part > STEEL > Accept > Done

Pro/ENGINEER Educational Edition (for educational use only)			
<u>Eile Edit View Insert Analysis Info Applica</u>	ations Tools ANSYS 9.0 Window Help		
🛯 🔁 🔮 🖓 🖓 🖾 🗠	ћ 🔓 н :::-		
	File Open     Look In     Dinesh     asm0001.asm     block.pt     Ink1.pt     Ink3.pt     setup_links.asm		
	Name       link2.pt         Type       Pro/ENGINEER Files (.prt, .asn         Open       Open Rep         Open       Open Rep		

File > Open > Select link2.prt



Edit > Setup > Material > Assign > From Part > STEEL > Done

LINK2 (Active) - Pro/ENGINEER Educational Edition (for educational use only)			
	<u>File Edit V</u> iew Insert <u>A</u> nalysis I <u>n</u> fo Application	ns <u>T</u> ools ANSYS 9.0 <u>W</u> indow <u>H</u> elp	
	မ်း 🔁 🖶 🖨 🕞 🖉 က က ရဲ	· 🛱 🏥 🗰 🗂 • 🛛 🔽 🎦 😵 🔍 🔍 🔍 🏕 🕮 🕬 🕼 🖉 🗗 🗗	
	∠ <u>,</u> / ×× ¥   <b>№</b>		
		File Open         Look In       Dinesh         asm0001.asm         block.ptt         ink1.pt         ink2.ptt         ink8.ptt         setup_links.asm	
000000		Name link3.prt	
		Type Pro/ENGINEER Files (.prt, .asn 💌 Sub-type	
		Open         Open Rep         Cancel         Preview >>>	

File > Open > Select link3.prt



### Edit > Setup > Material > Assign > From Part > STEEL > Done



FILE > NEW > ASSEMBLY > NAME FourBar > OK

FOURBAR (Active) - Pro/ENGINEER Educational Edition (for education	nal use only)	-O×	Menu Manager
Eile Edit View Insert Analysis Info Applications Tools ANSYS 9.0	<u>V</u> indow <u>H</u> elp		- ASSEM SETUP
DCOLOOBBEN NO	u = ,   , , , , , , , , , , , , , , , , ,	1	Mass Props
		<u>a</u>	Accuracy
			Dim Bound
			Dimension
			Ref Dim
		60	Name
		/ 🗞	Geom 101 Surf Finich
			Notes
		$\sim \alpha$	Symbol
>		×× +	Grid
		××× 110	Tol Setup
			Ref Control
		di la companya di la	Comp Interface
			Designate
	1	2	Flexibility
	***	a	Done
	🛄 Ur	nits Manager	×
	Syste	ems of Units Units	
	Changing Model Units	entimeter Gram Second (CGS	
\$	Model Parameters	oot Pound Second (FPS)	New 1
		ich Ibm Second (Pro/E Defau ich Pound Second (IPS)	lt)
		leter Kilogram Second (MKS)	Lopy
		illimeter Kilogram Sec (mmKs)	Edit
	C Convert dimensions (for example 1" becomes 25.4mm)	illimeter inewton Secona (mm	Delete
	Interpret dimensions (for example 1" becomes 1mm)		Info
	OK Cancel	escription	
<ul> <li>base window cannot be closed.</li> <li>New objects created with this educational version of Pro/ENGINEER will not be</li> </ul>		Inch Pound Second (IPS)	12.
compatible with commercially licensed Pro/ENGINEER software.	Ler	gth: in, Force: lbf, Time: sec,	Temperature: F
All the objects which were not displayed have been erased.	d de la constante de		
<ul> <li>Using the template default C:(Program Files(proewildrire 2.0)(templates(inibs_as))</li> </ul>	m_design,asm as the template.	Chur	
	Smart	LIOSE	

SET UNITS FOR ASSEMBLY Edit > Setup > Units > Select Inch Pound Second > Set > Select the 1st option > Ok > Close > Done



Click on "Add Component to the assembly" icon

🧧 FOURBAR (Active) - Pro/ENG	INEER Educational Edition (for educational use only)
<u>File E</u> dit <u>V</u> iew <u>I</u> nsert <u>A</u> nalysis	Info Applications Tools Window Help
	🗠 🗠 🖻 🛱 🛱 🎬 🗰 🗂 🕶 🛛 😓 🛠 🍕 🔍 🔍 🗖 🥵
	🛄 Open 🔀
	Look In 🛅 Four_bar 🚽 🖻 📃 🇀 🕍 🗟 🗮 🐄
	<b>block.prt</b>
	□ link1.prt □ link2.prt
	☐ link3.prt
×	
>	
20	
20 A	
MUM .	Name block.prt
	Type Pro/ENGINEER Files (.prt, .asn 💌 Sub-type
	Open         Open Rep         Cancel         Preview >>>

# Select block1.prt > Open

📕 FOURBAR (Active) - Pro/ENGINEER Educational Edition (fo	r educational use only)	Component Placement
Eile Edit View Insert Analysis Info Applications Iools V	/indow Help	
		Place Move Connect
		Constraints
		Type Offset
		Automatic 🗾
*		
	AT	
>		
		CAssemble component at default location
		Assembly Reference
		Placement Status
		No Constraints
>		
		OK Preview Cancel
		Select X
		OK Cancel

Click on the icon "Assemble Component at default location"



Click on Ok

📒 FOURBAR (Active) - Pro/ENGINEER Educational Edition (for educational use only)		
<u>File E</u> dit <u>V</u> iew <u>I</u> nsert <u>A</u> nalysis I <u>n</u> fo A	Applications <u>T</u> ools <u>W</u> indow <u>H</u> elp	
D 📂 🛛 🕹 🗛 🖓 🗠   🕫 (	> 🖻 🛱 🎬 🎬 🗰 🗂 🖌 🔯 🦑 🔍 으, 🔍 🏕	
] Ø Ø Ø 👩 🛛 🖊 👗	🔆 🛛 💦	
	📋 Open 🔀	
	Look In 🗋 Four_bar 💽 🖻 🗈 😂 🛣 🏣 🦄	
	block.prt	
	Ink2.pt	
>		
	• I	
	Name link1.prt	
	Type Pro/ENGINEER Files (.prt, .asn 💌 Sub-type	
	Open         Open Rep         Cancel         Preview >>>	

Click on "Add Component to the assembly" > link1.prt > Open



Click on CONNECT Tab at top-right



Keep the default "Pin" joint > Axis Alignment > Select A1 and A3 axes (Yellow Arrows) Translation > Select the surfaces as shown (Green Arrows)



#### Click on Move Tab and rotate the link to required position

E FOURBAR (Active) - Pro/ENGINEER Educational Edition (for educational use only)			
<u>Eile E</u> dit <u>V</u> iew Insert <u>A</u> nalysis I <u>n</u> fo Applications <u>T</u> ools <u>W</u> indow <u>H</u> elp			
D ≥ D ≜ G G   ∽ ~ B B B B P P M C -   D > % & Q Q D → C			
🛄 Open 🔀			
Look In 🗀 Four_bar 🗾 🗈 📃 😂 🖄 🔚 🎽 🐫			
block.prt			
ink1.pt			
ink3.prt			
Name link2.prt			
Type Pro/ENGINEER Files (.prt, .asn Sub-type			
Open         Open Rep         Cancel         Preview >>>			

Click on "Add Component to the assembly" > link2.prt > Open



Keep the default "Pin" joint > Axis Alignment > Select A4 and A3 axes (Yellow Arrows) Translation > Select the surfaces as shown (Green Arrows)



#### Insert Base Block Again

Select block1.prt > Open



Place (not Connect) First Align Constraint – surfaces indicated by yellow arrows Second Align Constraint – surfaces indicated by green arrows Third Mate Constraint – surfaces indicated by orange arrows



#### Select link3.prt > Open



Keep the default "Pin" joint > Axis Alignment > Select A4 and A3 axes (Yellow Arrows)

Translation > Select the surfaces as shown (blue Arrows)

E FOUR_BAR (Active) - Pro/ENGINEER Educational Edition (for educational use only)	Component Placement
Eile       Edit       Yiew       Insert       Analysis       Info       Applications       Icols       Window       Help $\square$	Place Move Connect
	Name Type   Connection_4 Pin     Constraints     Rule Dffset     Axis alignment     Translation     Translation     Component Reference   LINK3: A_3     Assembly Reference   LINK2: A_4   Placement Status Connection Definition Complete.
<ul> <li>Select aligning axis or edge on other part.</li> <li>Select aligning axis or edge on other part.</li> <li>Select a point or planar surface on one part.</li> </ul>	OK Preview Cancel

Click on ok. Add one more Connection > Pin joint



Align the A4 with A1 and for Translation – Select the surfaces as indicated by green arrows.



Mechanism Mode – Select Mechanism option from the menu bar.



To define the driver, select the Define Servo Motors icon.


Click on New button to define the parameters of the servo motor.



Select the JOINT 1 axis indicated by orange colored arrow to be the servo motor axis. > Enter 10800 > OK > Close



Click on Define Initial Conditions to set the initial parameters.



Select New to define new conditions.



## Define any initial desired parameters.



## Click on Run Analysis icon as indicated



## 1. Do KINEMATIC Analysis First

Click on New.



Note that the initial configuration is the current position.



Select Replay previously run analyses to display the motion.



Click on Play current result set to run the analysis.



Click the play option to play the animation.

Ľ	FOUR_BAR (Active) - Pro/ENGINEER Educational Edition (for educational use only)		<u>-8×</u>
!	Eile Edit ⊻iew Mechanism Analysis Info Applications Tools Window Help		_ 뭔 ×
		×	⊇ommon Tasks → 🐥
		• € © © % 0   € •	
		enerate mea	sure results of analyses

Click on the graph icon to generate the graphs.



Click on create new measure.



Use default name measure1. Select Type of parameter > Position > select the JOINT 3 axis > OK.



Select the Graph icon at the Top.



This gives the position/displacement of joint shown in red.



Graphs can be obtained for various options shown.



Click on the icon shown to generate dynamic analysis of this Mechanism



Click on Analysis Icon > New > Select Type Dynamic > Run > OK > Close

Note that the initial condition is the current state.



Select Generate Measure Results of Analyses to obtain the value of forces on the selected joints.



## Select Connection Reactions to obtain Reactions at the joints.



Select the joint and the measure to be plotted onto the Graph. In this case the Radial Forces are computed for all the Joints.

ľ	🔲 AS	M0001	(Activ	e) - Pro/	'ENGINEE	R Educa	ational Edi	tion (for	educationa	al use or	ıly)				🛄 Measure Definition 🛛 🔀
	Eile	Edit Vi	ew M	echanism	Analysis	Info	Application	is <u>T</u> ools  []].▼	ANSYS 9.0	<u>W</u> indov • 🎇	w <u>H</u> elp ⊕ ⊖	. 🔍 🏕	- 🖧 🎒		Name measure1
	<b>N</b> ?														Connection Reaction
								A 4					A 3		Connection Type Joint Joint Connection_1 Component Radial Force Expressed In Body1 LCS Evaluation Method Each Time Step
	· · · · · · · · · · · · · · · · · · ·			ŗ	A 1 A 4 Z			A_1 4	OK Apply Cancel ↓ ↓ ↓						

Now the JOINT 2 is selected and component to be plotted – Radial Force > OK.



Select measure2 and Analysis Definition2 > Click on the Graph icon at the top left.



The Graph shows the Connection Reactions at JOINT 2.



File > Export Text



One can also write the results into Text file. Later this can be opened in notepad or wordpad.

Slides 65 through 73 do the same for JOINTS 1, 3, & 4.

Skip ahead to Slide 74



Select JOINT 1 > component to be plotted – Radial Force > OK



Select measure3 and Analysis Definition2 > Click on the Graph icon at the top left



The Graph shows the Connection Reactions at JOINT 1.



Select JOINT 3 > component to be plotted – Radial Force > OK



Select measure4 and Analysis Definition2 > Click on the Graph icon at the top left



The Graph shows the Connection Reactions at JOINT 3.



Select Fourth Joint > component to be plotted – Radial Force > Ok



Select measure5 and Analysis Definition2 > Click on the Graph icon at the top left


The Graph shows the Connection Reactions at JOINT 4.



Create new measure > Net load > (pick the servo motor)

Information note:

To verify this analysis with an existing SI analysis everything was switched to SI for the Torque calculation.

Note on previous slide that the measure units are m-N as are the torque results on the next slide.

To verify these results, either convert your lbf-in torque to N-m for comparison or convert units during the analysis as we did.

## Servomotor Torque in m-N



## Fin