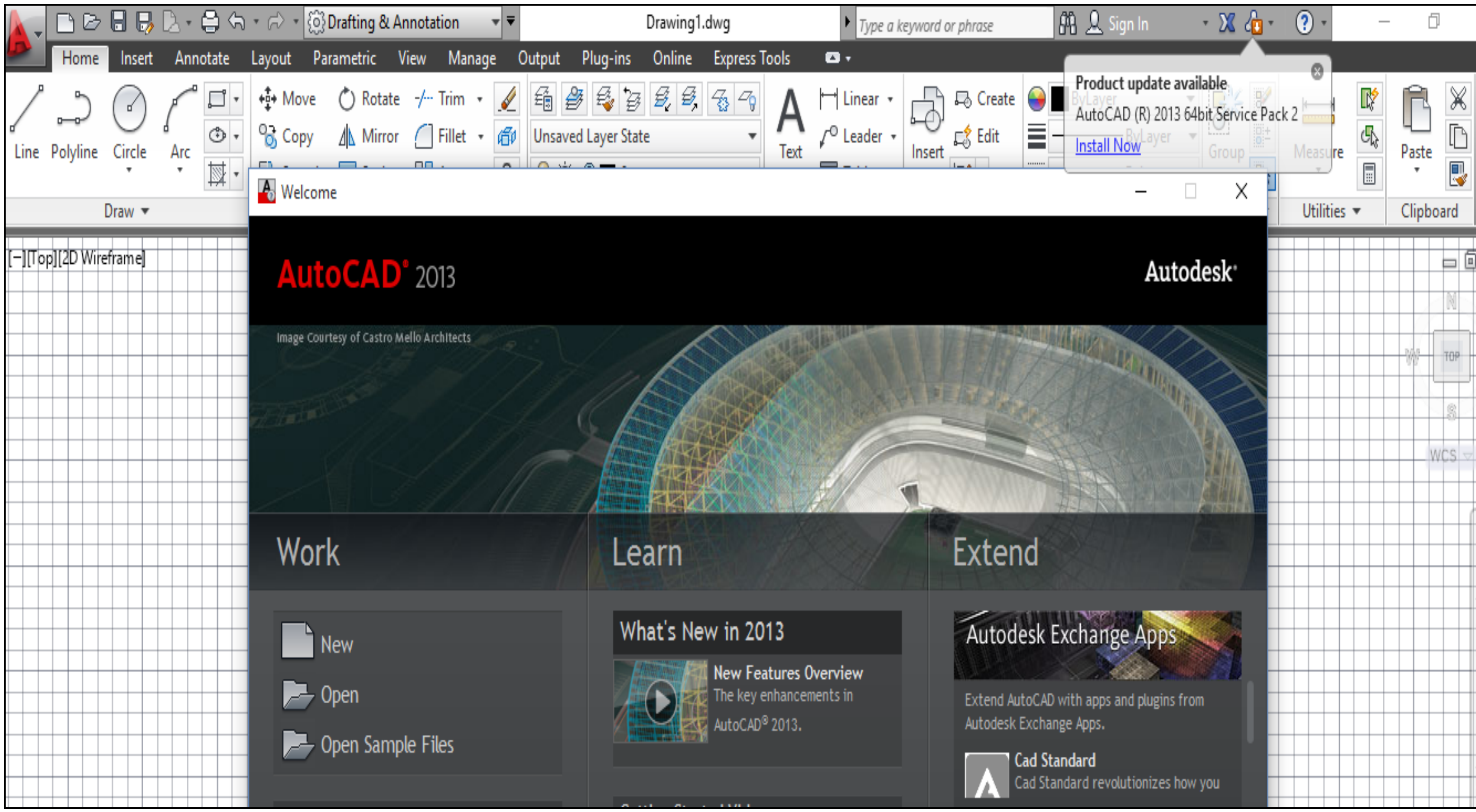
MECHANISM DESIGN

CHAPTER 7: COMPUTER-AIDED MECHANISM DESIGN

Shamsul Anuar Shamsudin
Mohd Nizam Sudin

AUTOCAD


Drafting & Annotation
Drawing1.dwg
Type a keyword or phrase
Sign In
Home
Insert
Annotate
Layout
Parametric
View
Manage
Output
Plug-ins
Online
Express Tools
Line
Polyline
Circle
Arc
Move
Rotate
Trim
Copy
Mirror
Fillet
Unsaved Layer State
Text
Linear
Leader
Insert
Create
Edit
Product update available
AutoCAD (R) 2013 64bit Service Pack 2
Install Now
Paste
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Utilities
Clipboard
[−][Top][2D Wireframe]
Welcome
AutoCAD 2013
Autodesk
Image Courtesy of Castro Mello Architects
Work
Learn
Extend
New
Open
Open Sample Files
What's New in 2013
New Features Overview
The key enhancements in AutoCAD 2013.
Autodesk Exchange Apps
Extend AutoCAD with apps and plugins from Autodesk Exchange Apps.
Cad Standard
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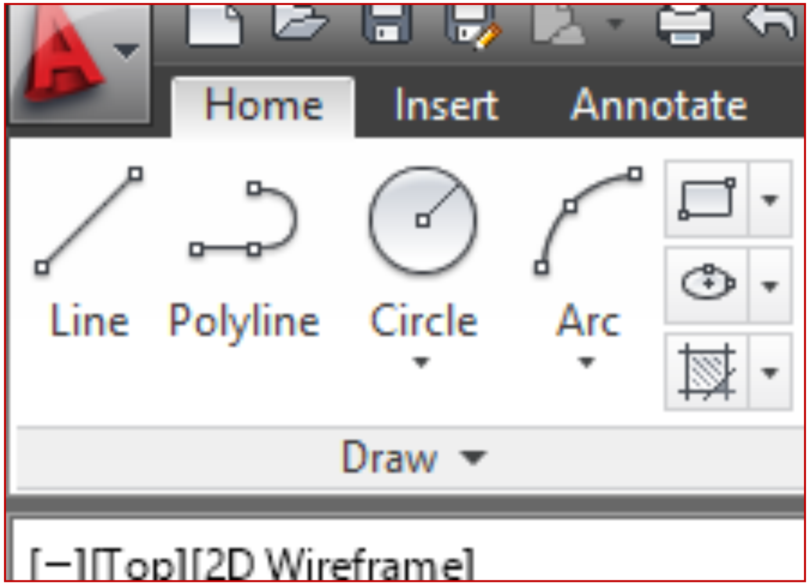
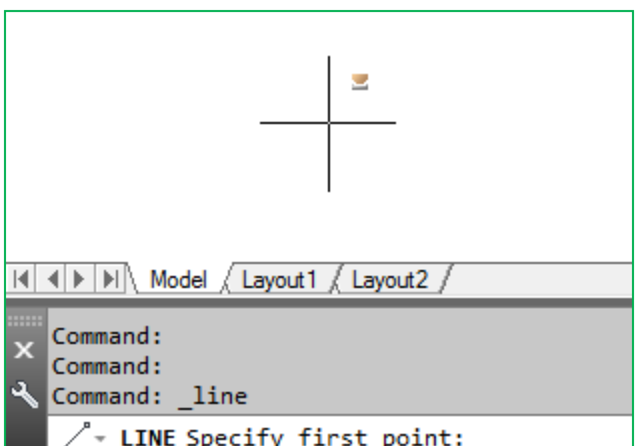
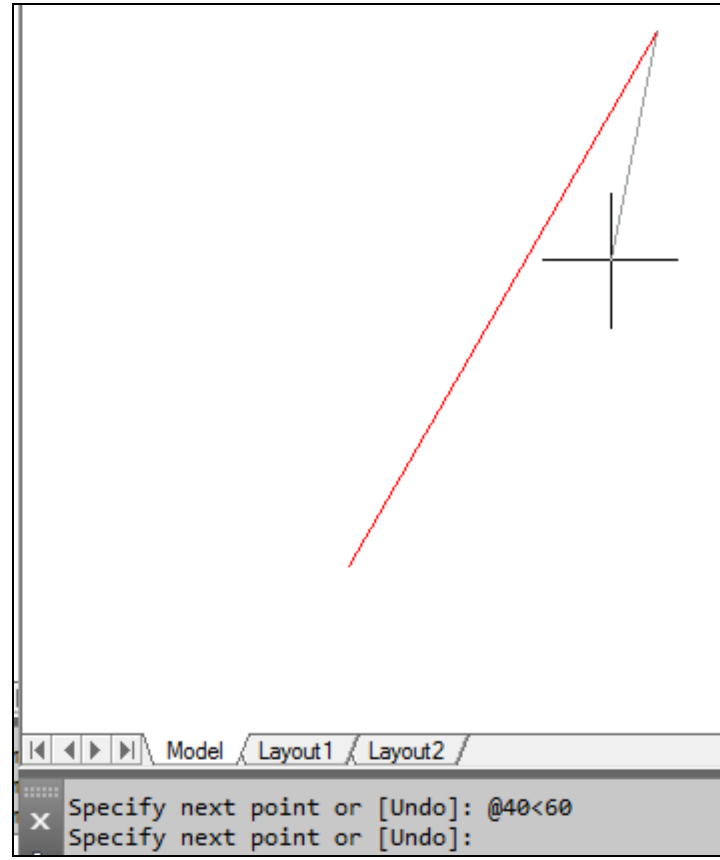
DRAWING



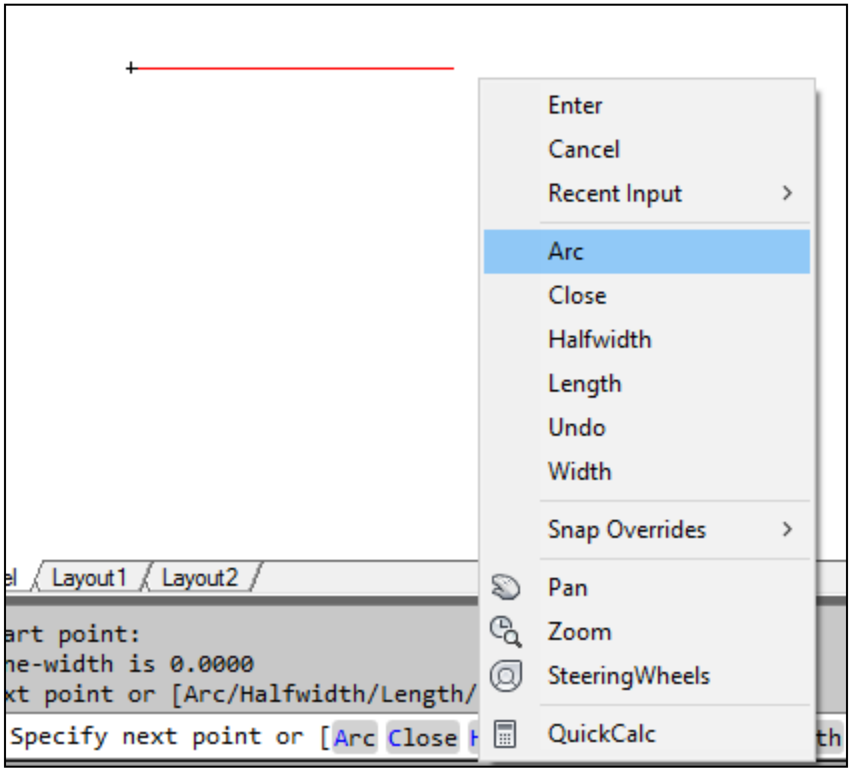


Line – use length and angle

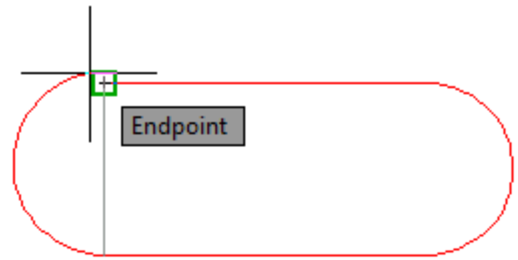


Hit **Esc** when done.

POLYLINE



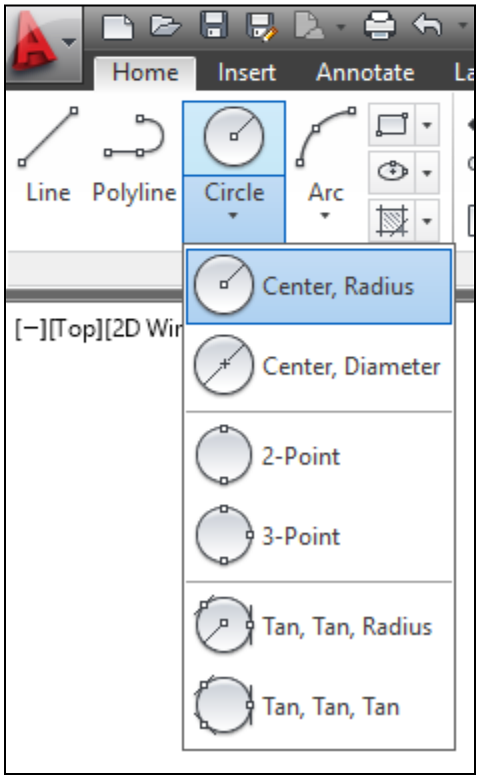
To go back to straight line, choose Line.

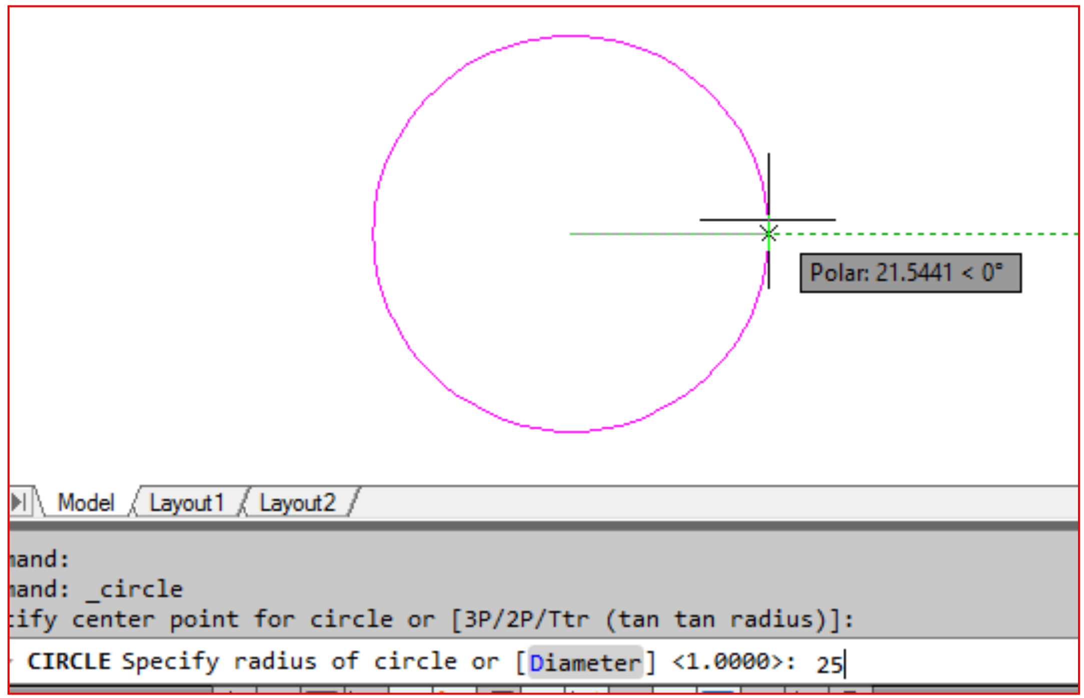


Hit **Esc** when done.

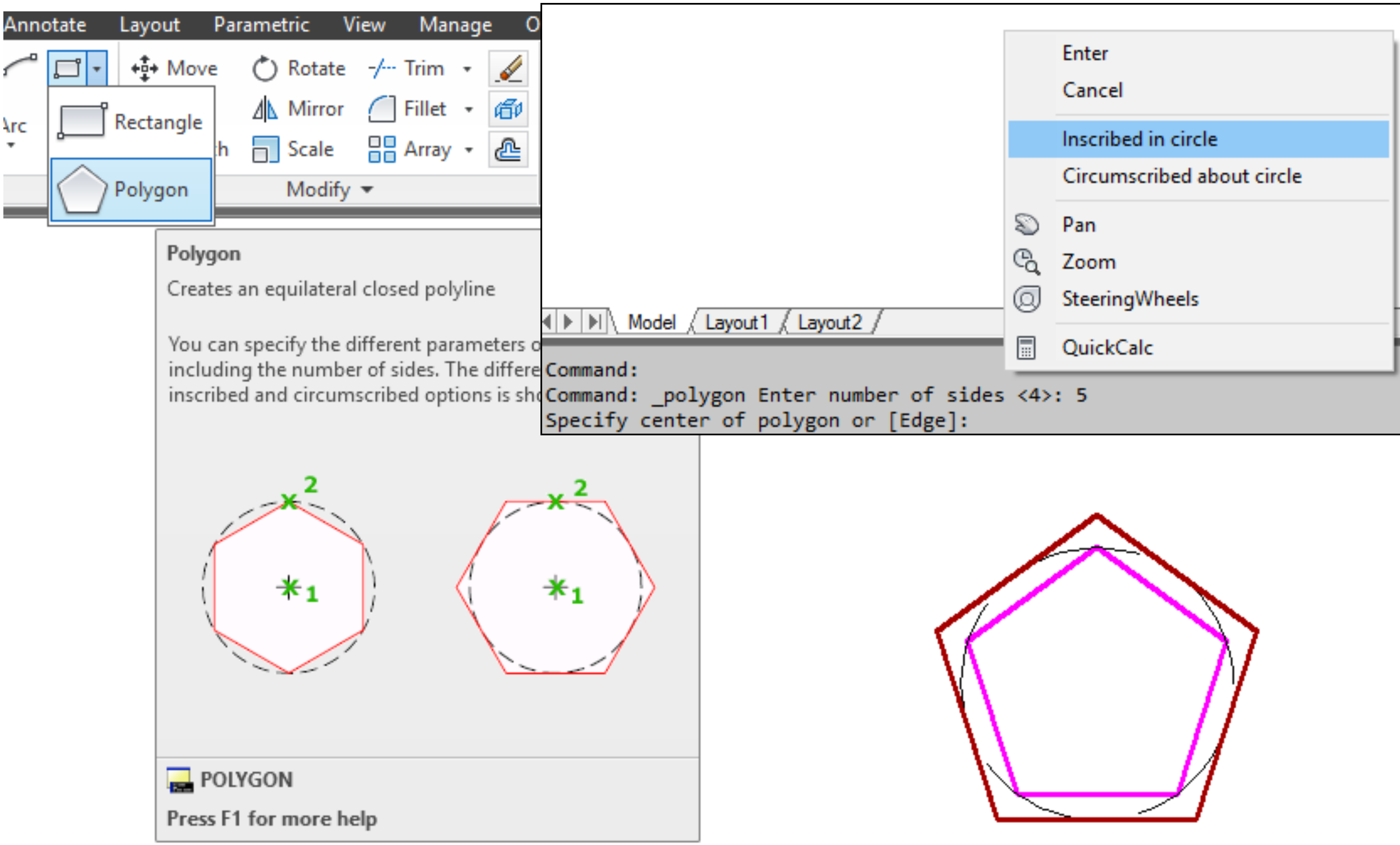
Similar to Line in many ways but capable of more. It can continue to create an arc and to change line width.

CIRCLE


Home
Insert
Annotate
Line
Polyline
Circle
Arc
[−][Top][2D Wir
Center, Radius
Center, Diameter
2-Point
3-Point
Tan, Tan, Radius
Tan, Tan, Tan


Polar: 21.5441 < 0°
Model
Layout1
Layout2
nand:
nand: _circle
cify center point for circle or [3P/2P/Ttr (tan tan radius)]:
CIRCLE Specify radius of circle or [Diameter] <1.0000>: 25

POLYGONS

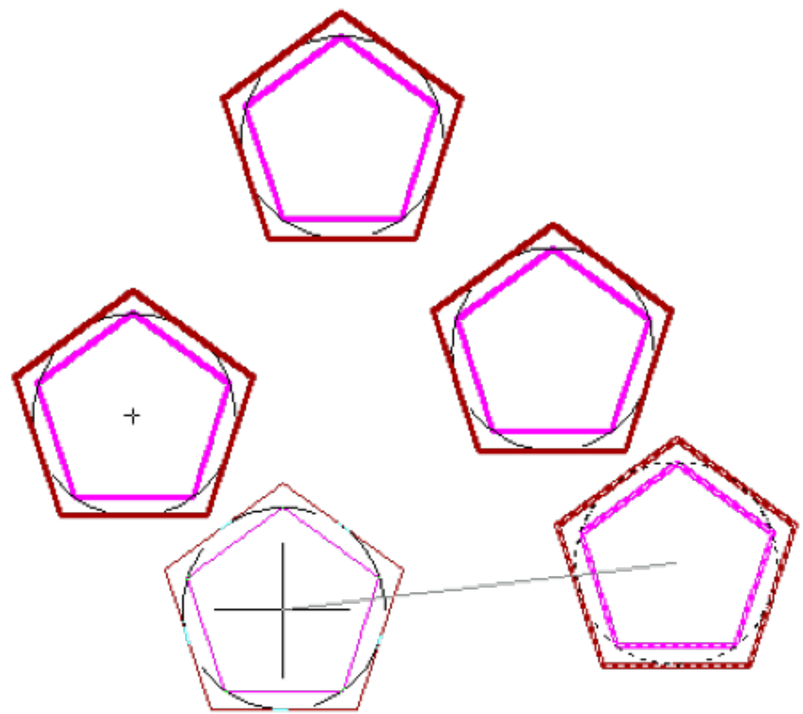


Annotate Layout Parametric View Manage
Move
Rotate
Trim
Rectangle
Mirror
Fillet
Arc
Scale
Array
Polygon
Modify
Polygon
Creates an equilateral closed polyline
You can specify the different parameters o
including the number of sides. The differe
inscribed and circumscribed options is sh
POLYGON
Press F1 for more help
Enter
Cancel
Inscribed in circle
Circumscribed about circle
Pan
Zoom
SteeringWheels
QuickCalc
Model
Layout1
Layout2
Command:
Command: _polygon Enter number of sides <4>: 5
Specify center of polygon or [Edge]:

MODIFY

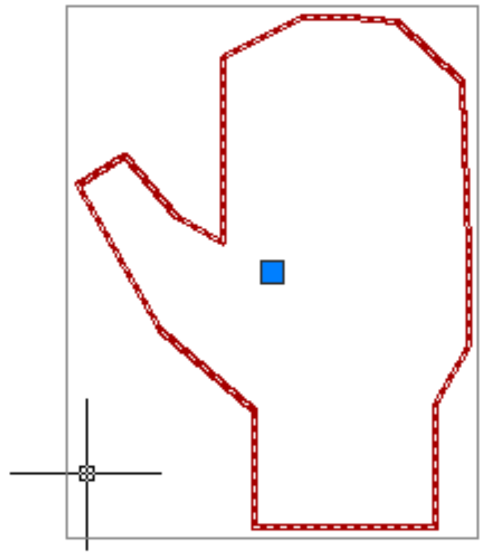
Main operations:

- ❑ Delete
- ❑ Trim
- ❑ Extend
- ❑ Lengthen
- ❑ Scale
- ❑ Move
- ❑ Copy
- ❑ Rotate
- ❑ Mirror



Copy

GROUP & BLOCK



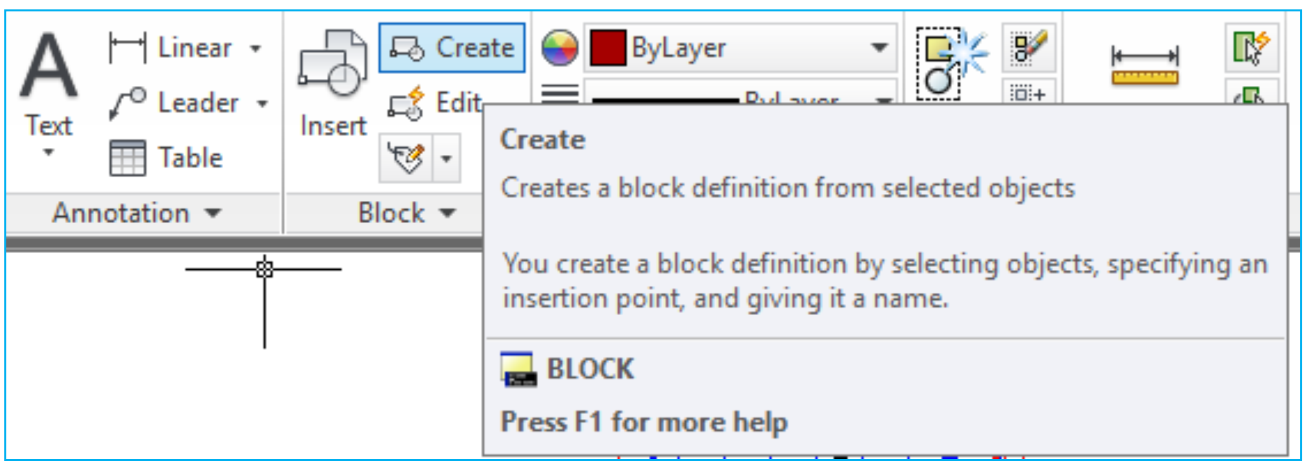
Model / Layout1 / Layout2

```
Specify second point or [Array/Exit/Undo] <Exit>:
Command: GROUP
Select objects or [Name/Description]: Specify opposite corner: 2 found
Select objects or [Name/Description]: N
Enter a group name or [?]: HAND1
Group "HAND1" has been created.
```

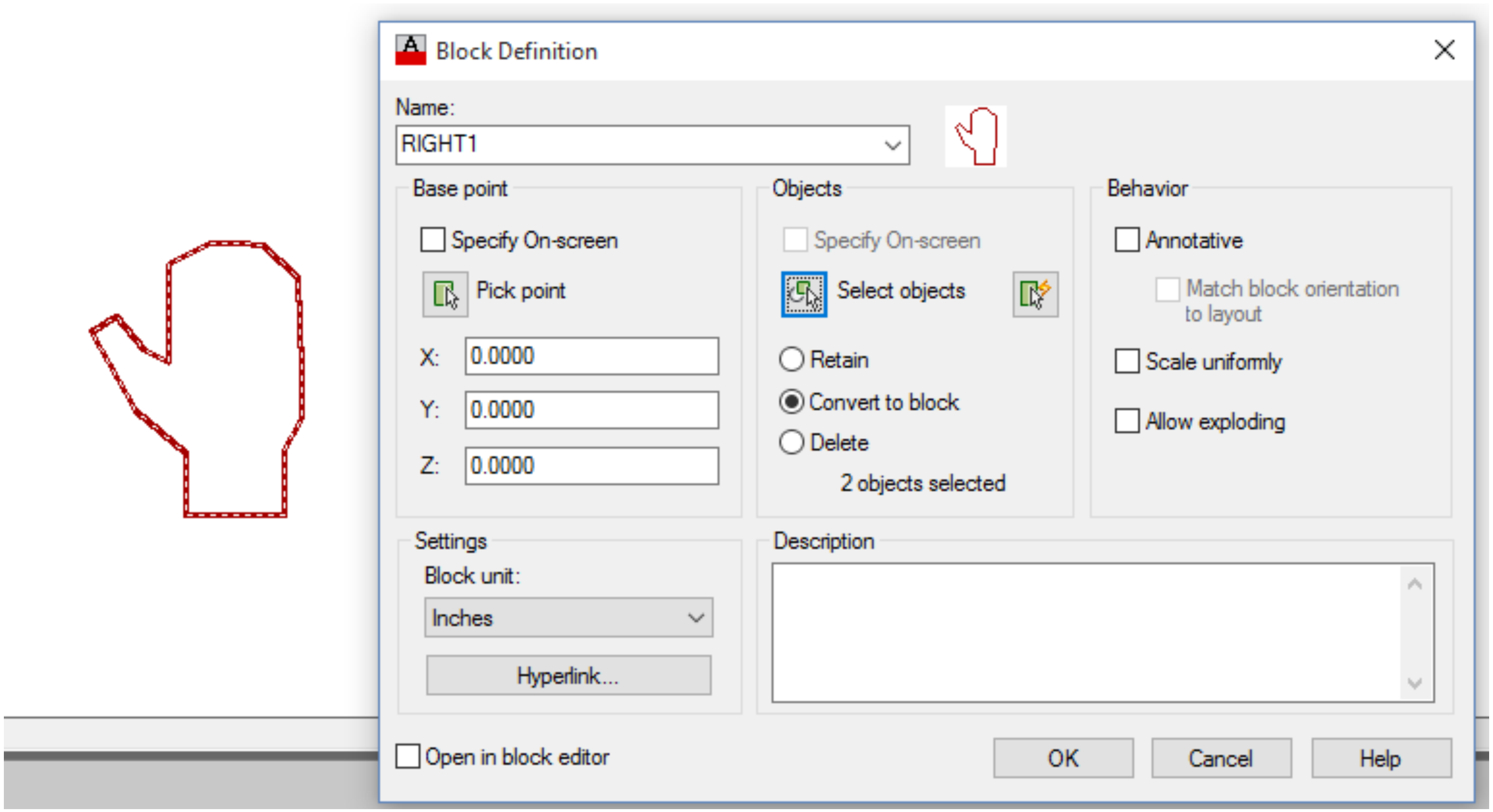
GROUP & BLOCK

Group – Just type ‘group’ and follow instructions

Block – Can be **inserted** in many copy with different scales and orientations. It is more powerful.

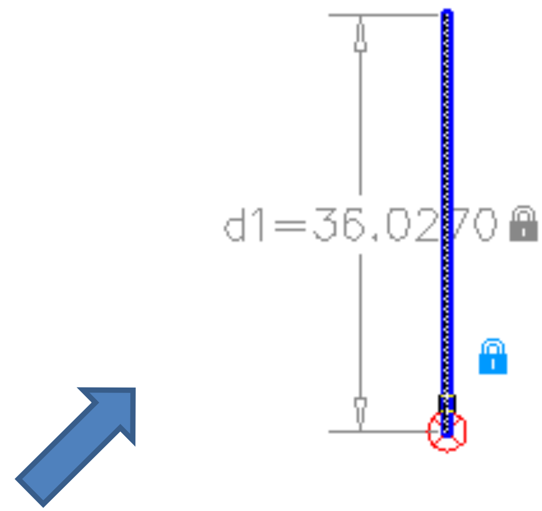


CREATE BLOCK

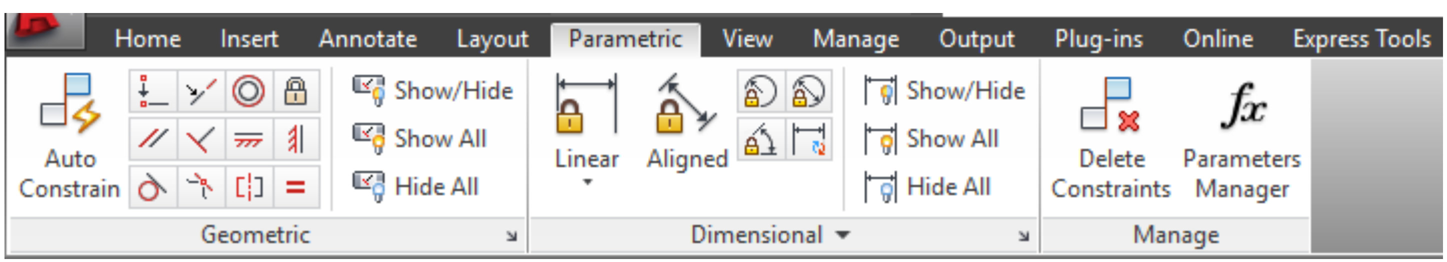


CREATE A LINK

1) DRAW A LINE



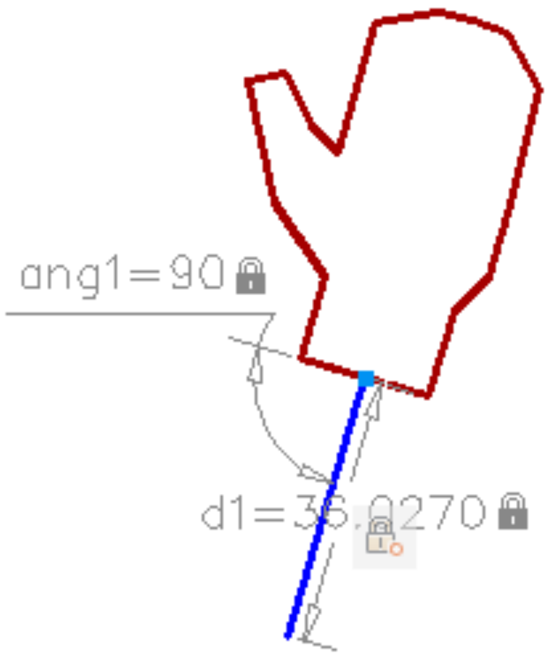
2) PARAMETRIC (CONSTRAINTS)



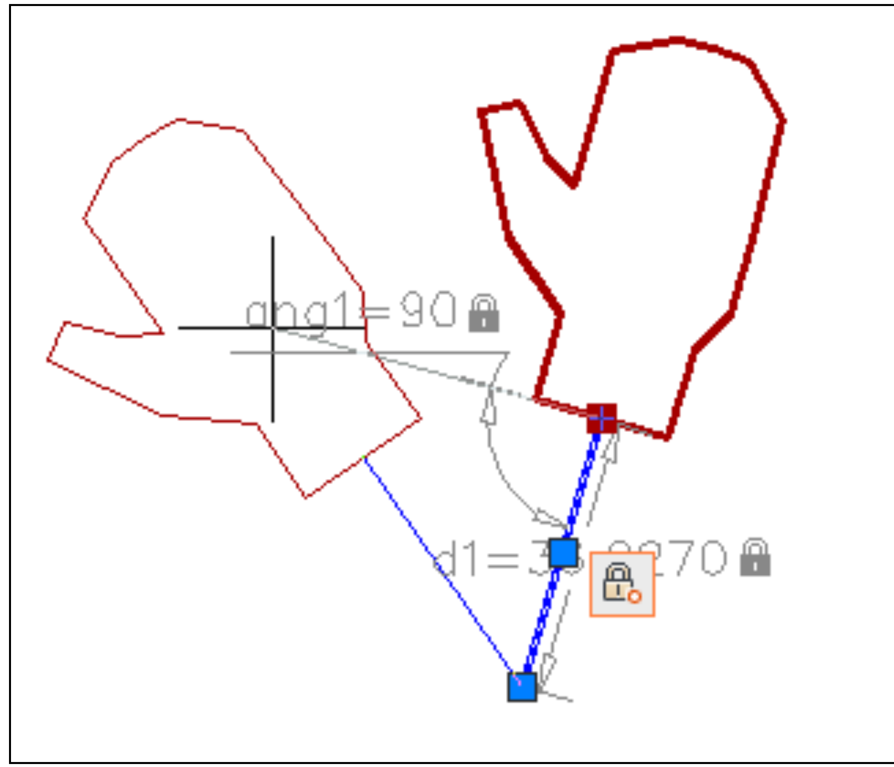
3) FIXED PIVOTS – FIX; JOINTS – COINCIDENT; ALIGNED ,ANGULAR, ETC.

ATTACH THE HAND

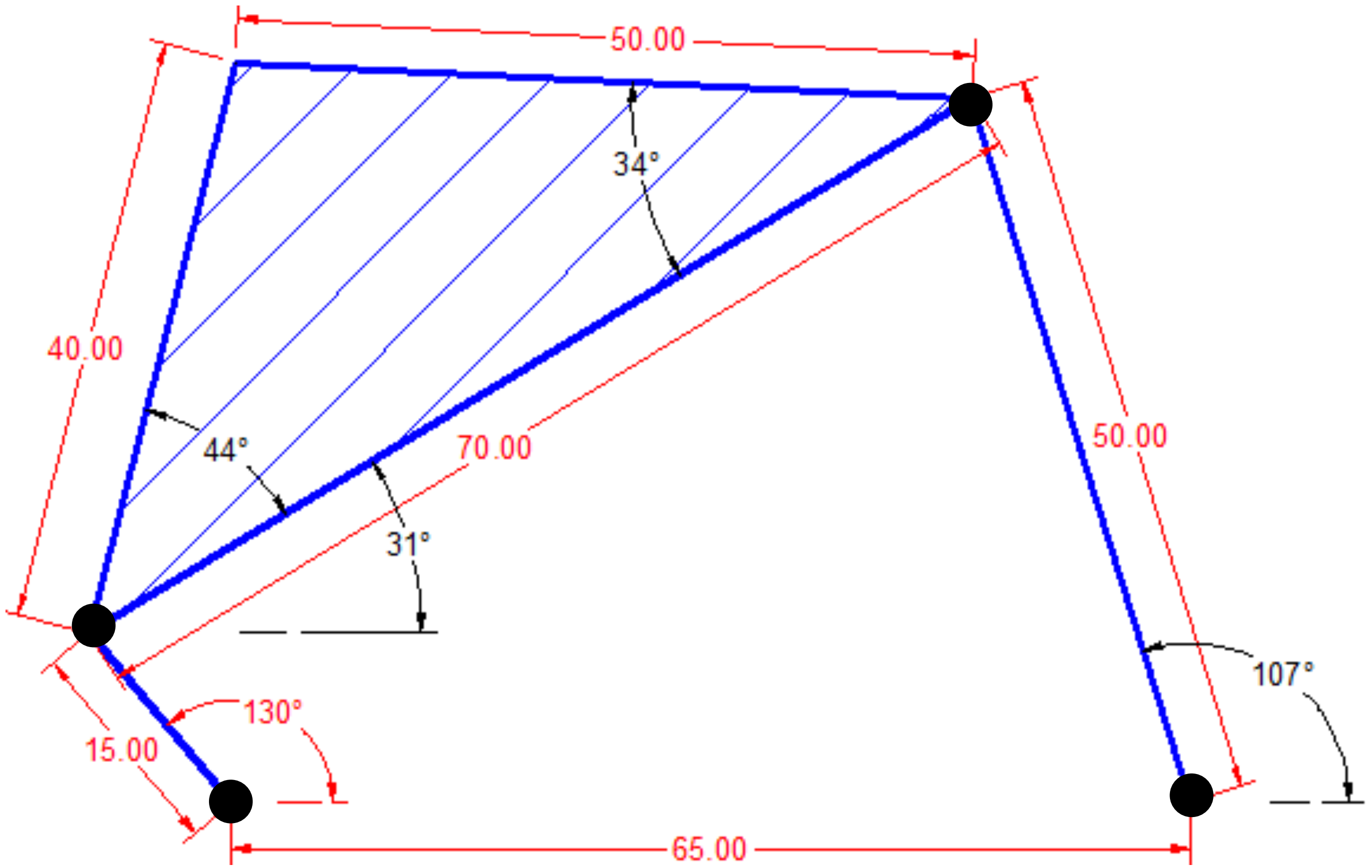
Use coincident and angular



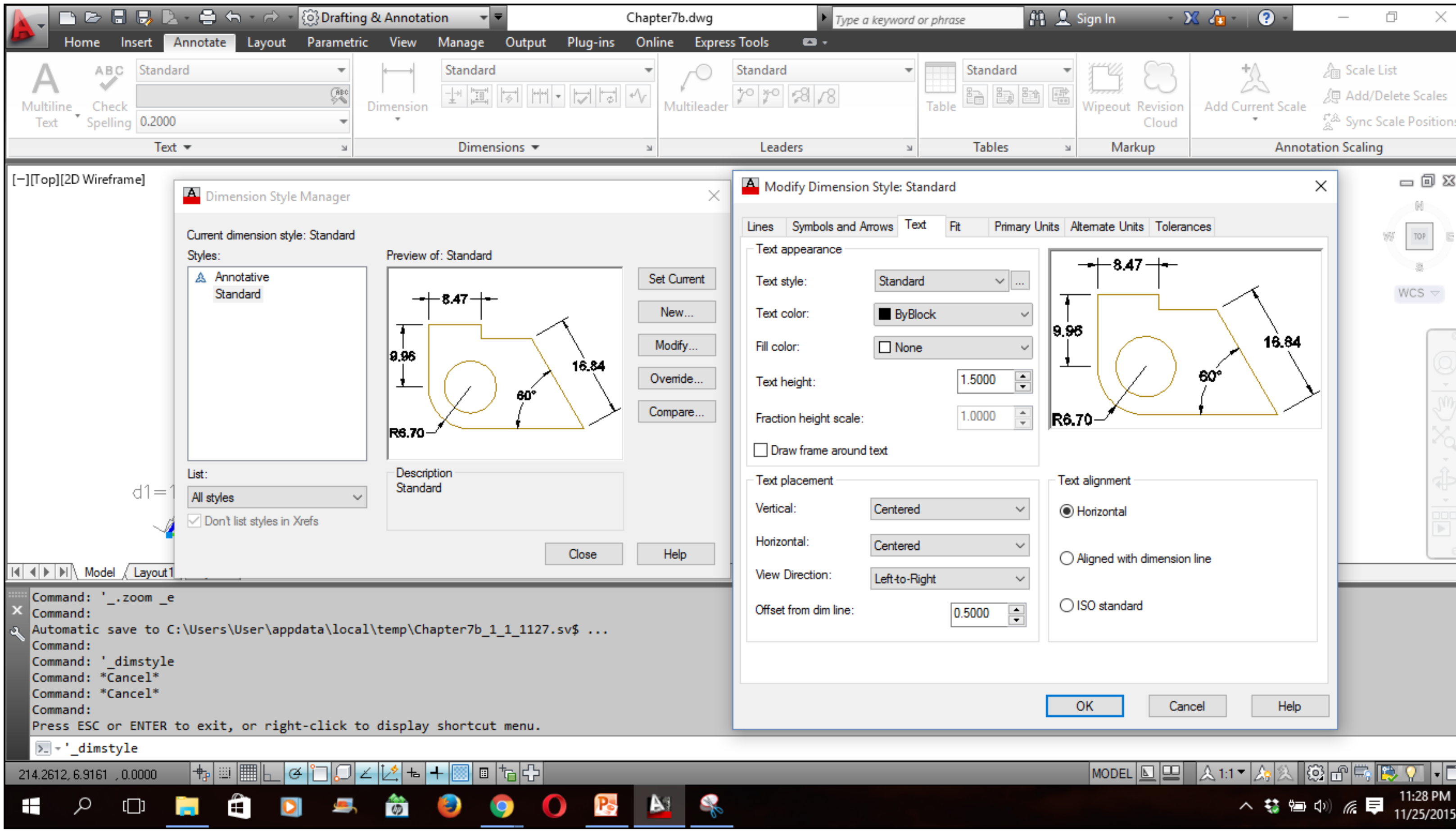
May use hand from **BLOCK** Only. You may create a Block from a Group.



FOUR-BAR MECHANISM EXAMPLE

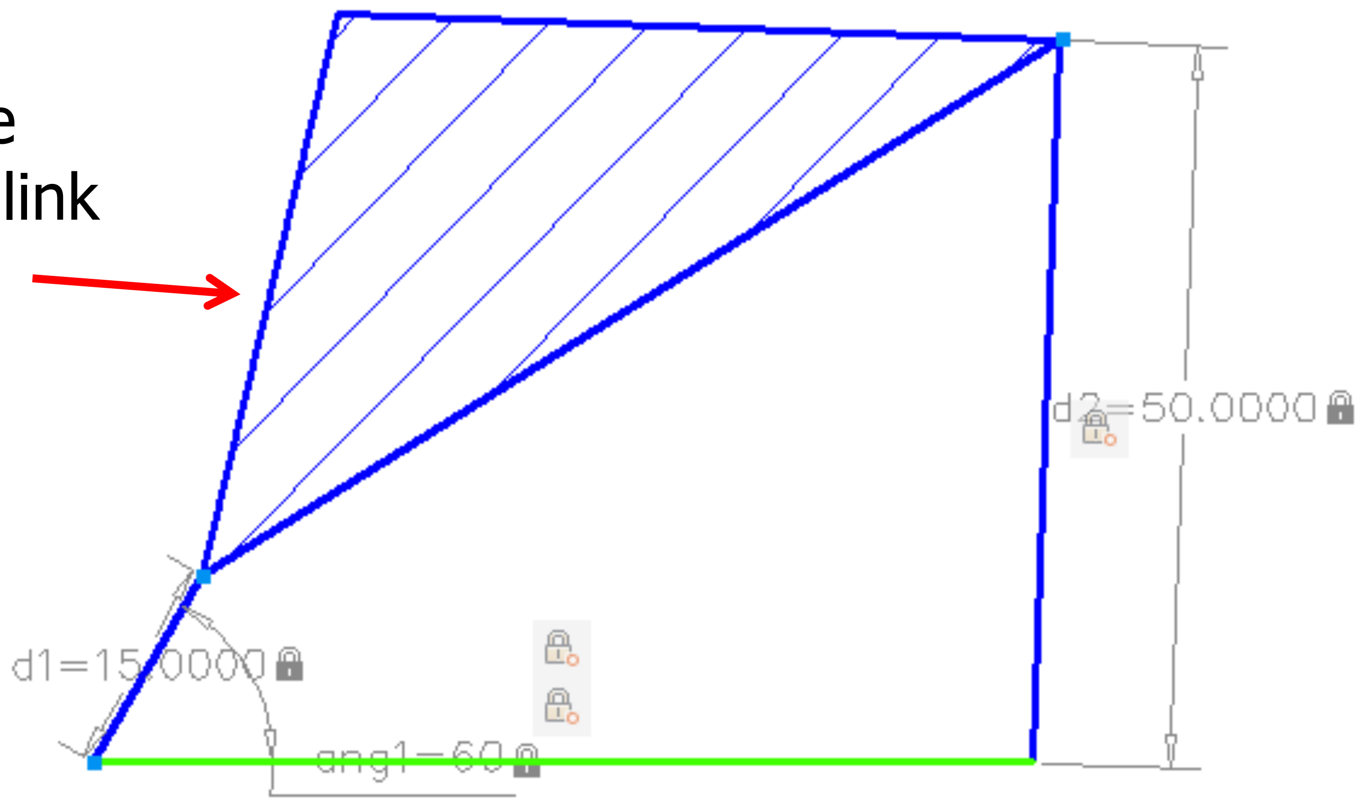


DIMENSION SETTING - ANNOTATE

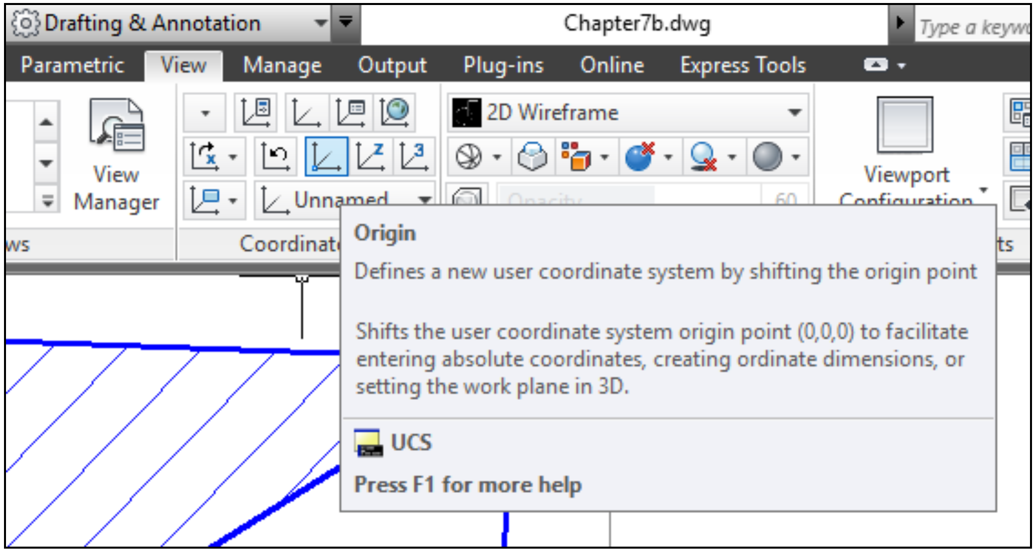


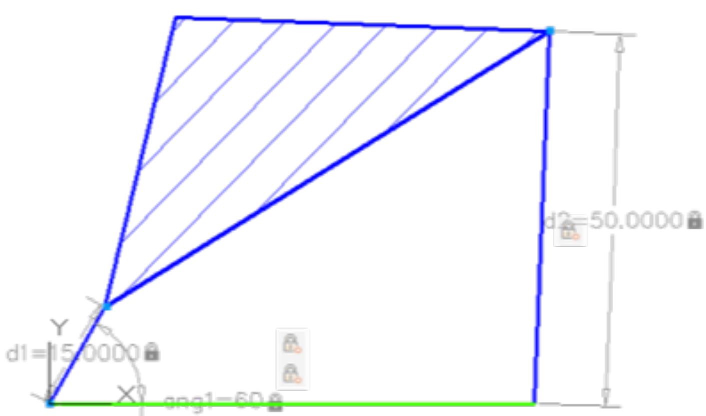
APPLY CONSTRAINTS

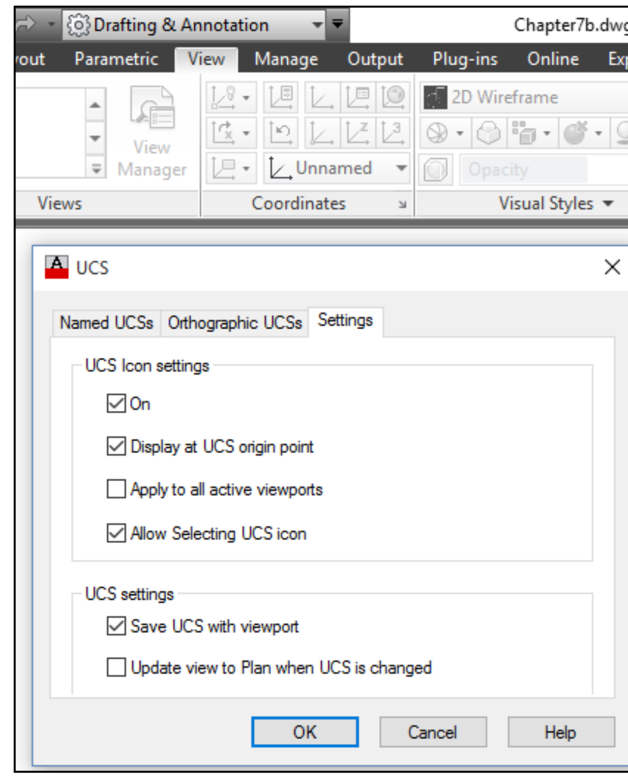
Turn the ternary link into a BLOCK



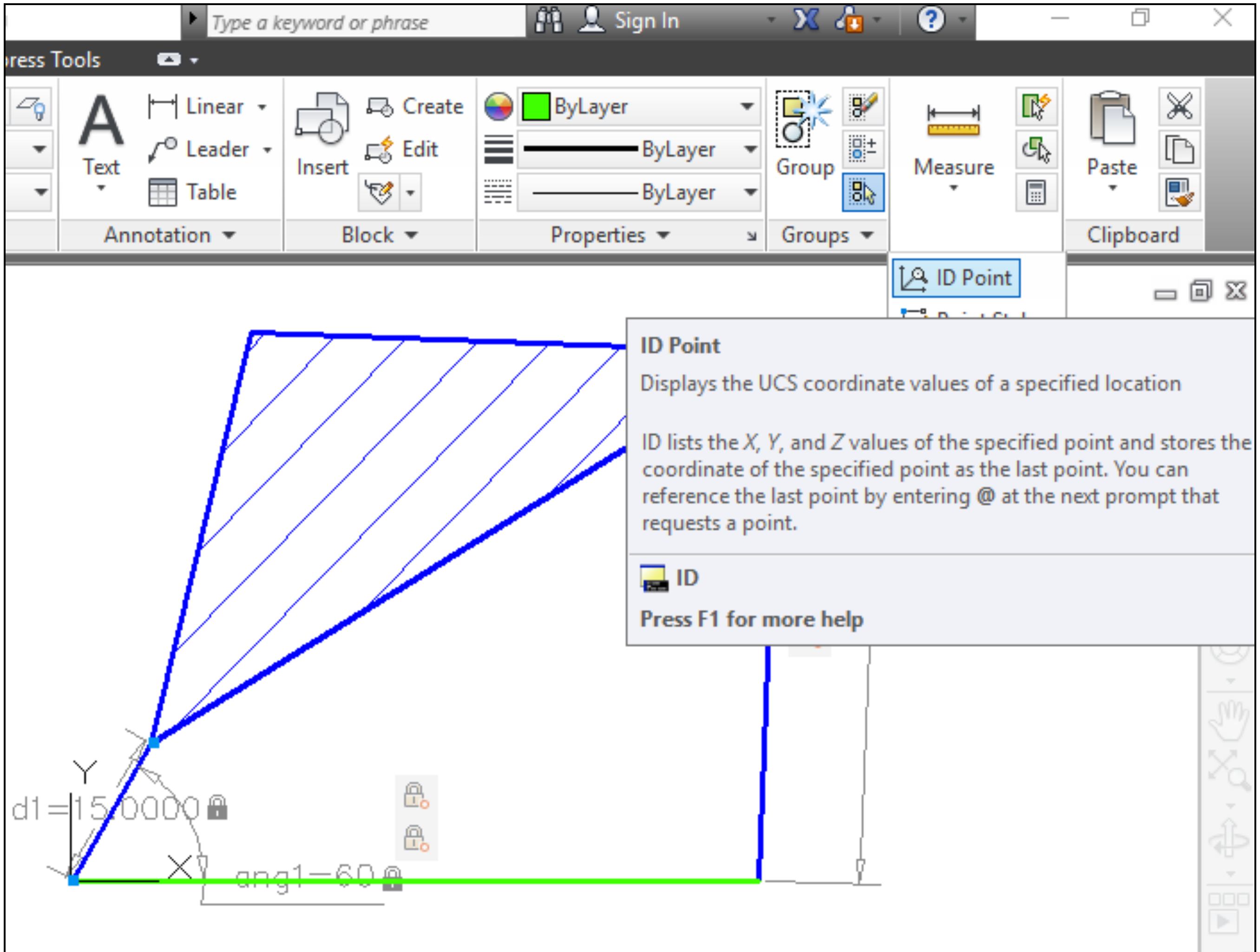
RESETTING COORDINATE ORIGIN





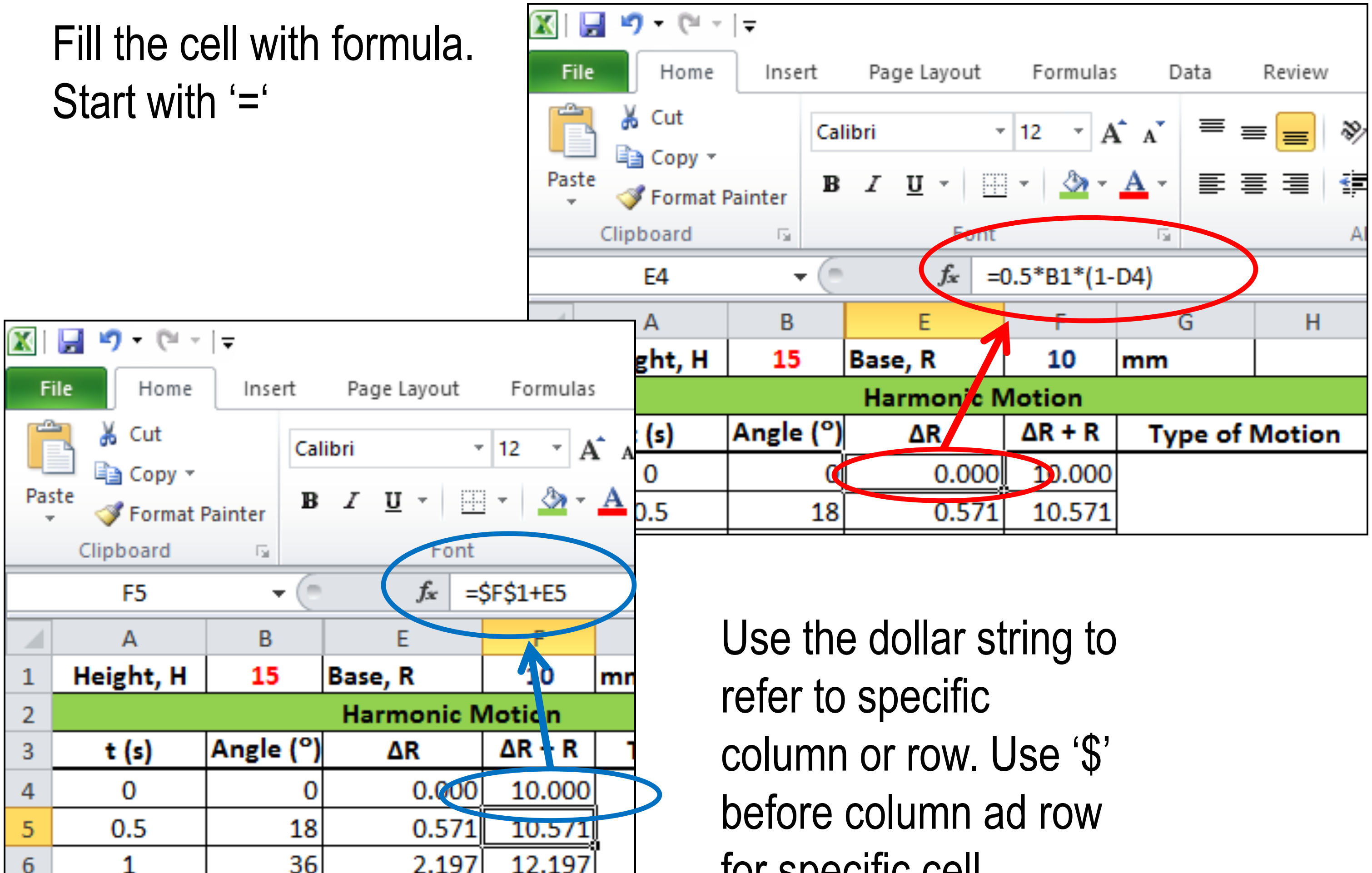


COORDINATE OF A POINT



MS EXCEL

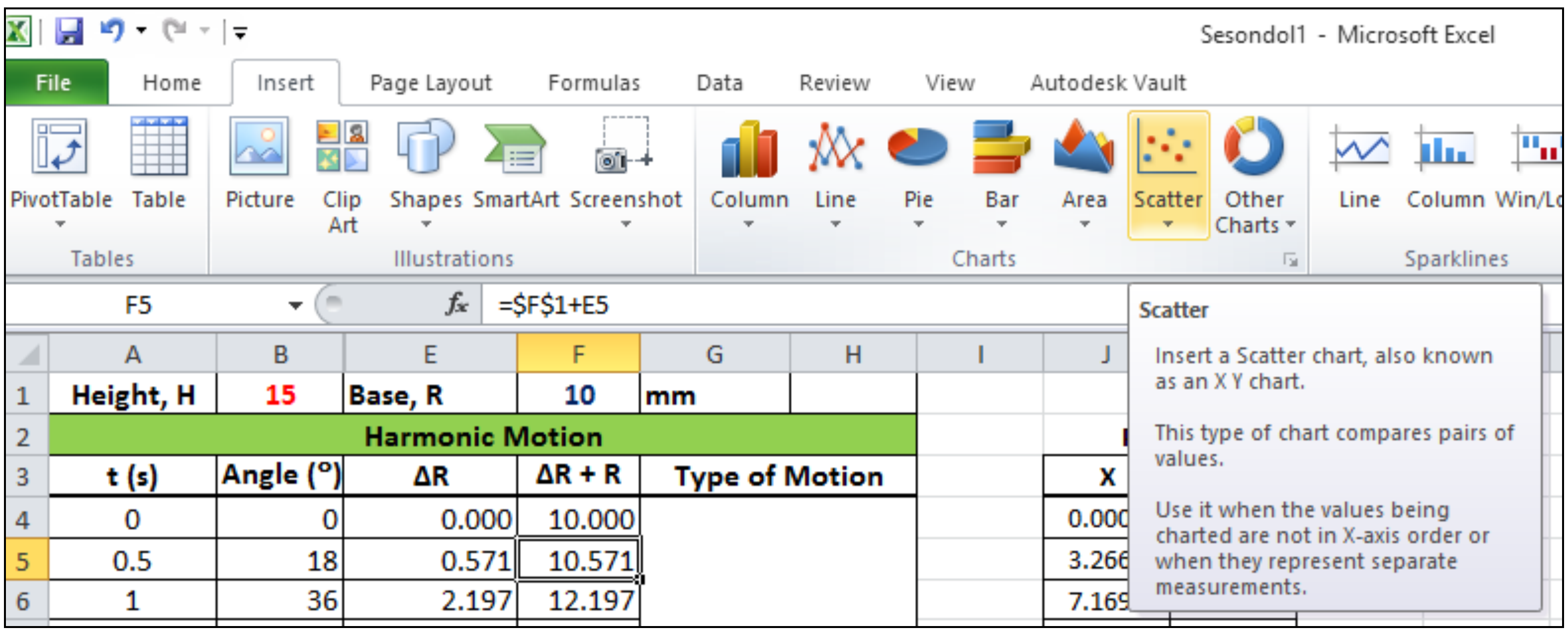
Fill the cell with formula.
Start with '='



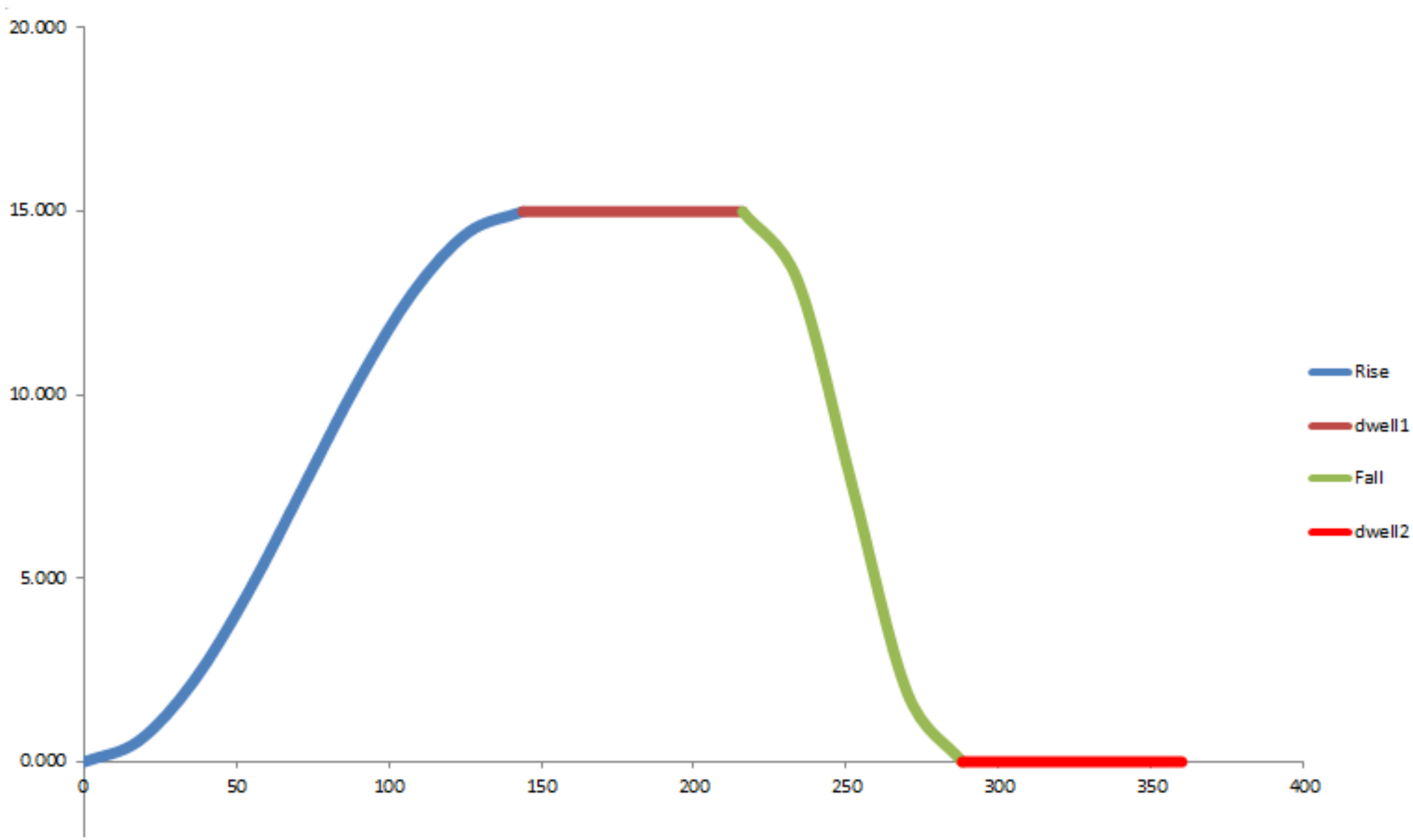
Use the dollar string to refer to specific column or row. Use '$' before column ad row for specific cell

GRAPH PLOTTING

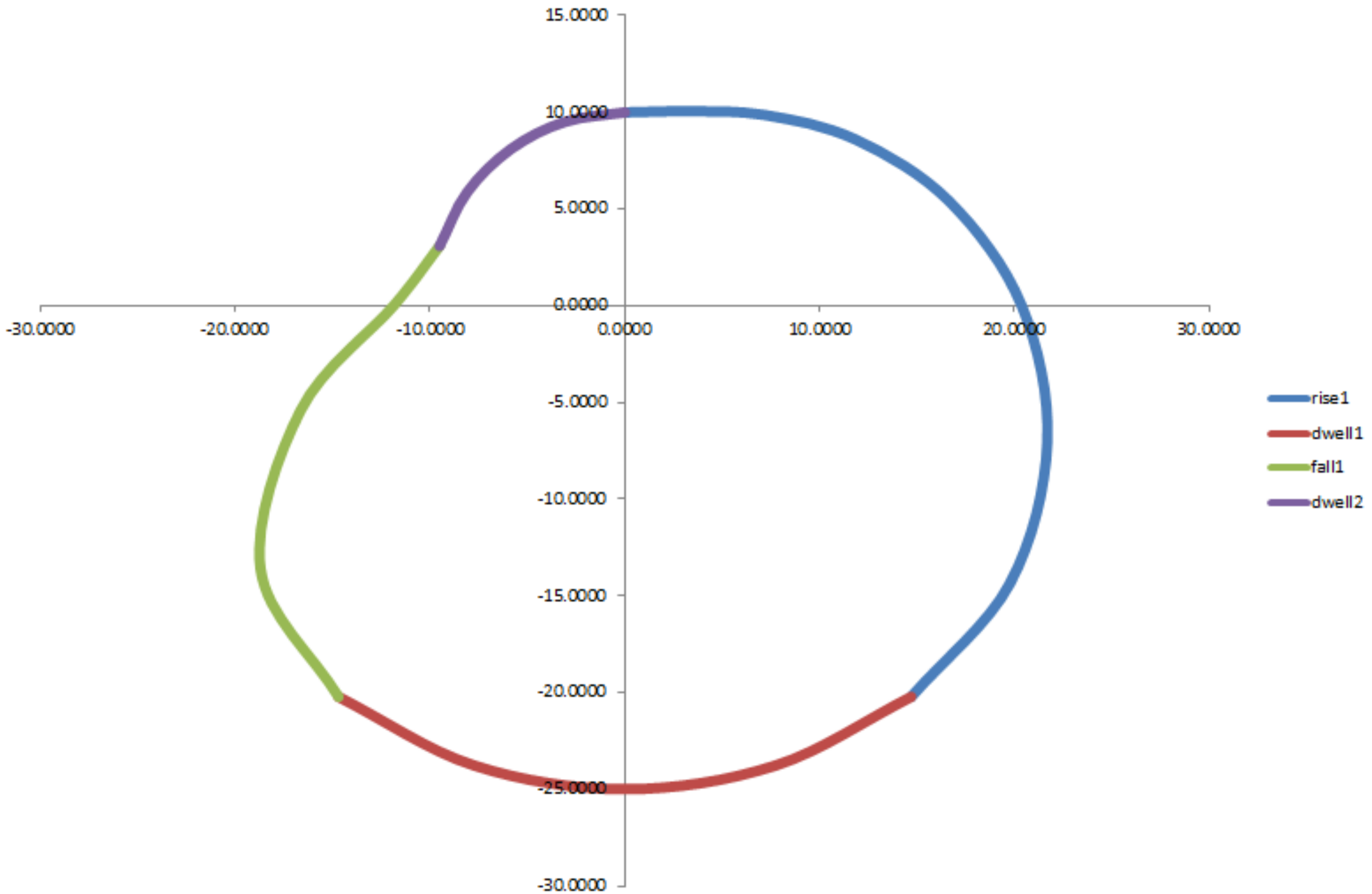
For XY plotting. Many other options here



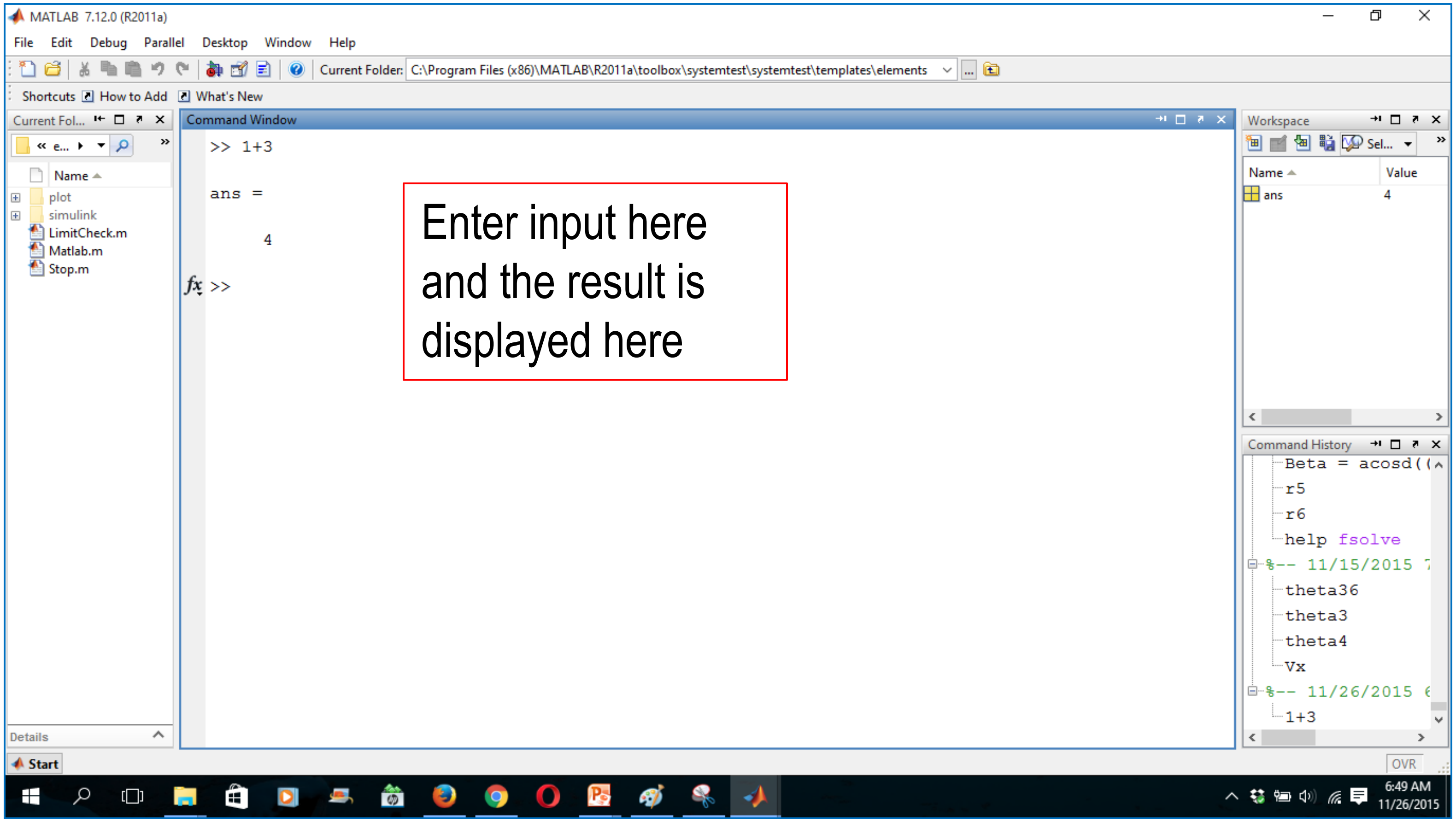
CAM EXAMPLE: DISPLACEMENT DIAGRAM



CAM EXAMPLE: CAM PROFILE



MATLAB


MATLAB 7.12.0 (R2011a)
File Edit Debug Parallel Desktop Window Help
Current Folder: C:\Program Files (x86)\MATLAB\R2011a\toolbox\systemtest\systemtest\templates\elements
Shortcuts How to Add What's New
Command Window
>> 1+3
ans =
4
Enter input here and the result is displayed here
Workspace
Name Value
ans 4
Command History
Beta = acosd((
r5
r6
help fsolve
%-- 11/15/2015
theta36
theta3
theta4
Vx
%-- 11/26/2015
1+3
plot
simulink
LimitCheck.m
Matlab.m
Stop.m

MATHEMATICAL EQUATIONS

Command Window

```
>> Campur = 2+5

Campur =

     7

>> Tolak = 9-15

Tolak =

    -6

>> Darab = 2*5

Darab =

    10

>> Bahagi = 27/9

Bahagi =

     3
```

$+$

$-$

$\times$

$\div$

Command Window

```
>> Kuasa = 2^3

Kuasa =

     8

>> Eksponensial = exp(1)

Eksponensial =

    2.7183

>> Saintifik = 1e3

Saintifik =

        1000
```

x^y

e^x

$x \times 10^y$

CLEANING UP

>>home – This clears up command window. It brings up the cursor and prompt. Previous commands and display hidden above the prompt.

>>clc – This also clears up the command window, but previous commands and output are erased entirely. However, the can still be called back by typing the variables or using the arrow up or down keys.

>>clear – It clears up the memory. All variables and values are erased completely. The Workspace window is empty.

>>% xx – This is to comment and MATLAB does not read it as commands. Otherwise an error warning is given.

```
>> clear
>> Saintifik
??? Undefined function or variable 'Saintifik'.
```

Undefined variable Error message

```
>> % Dude, what up?!
>>
```

Inserting comments with '%'

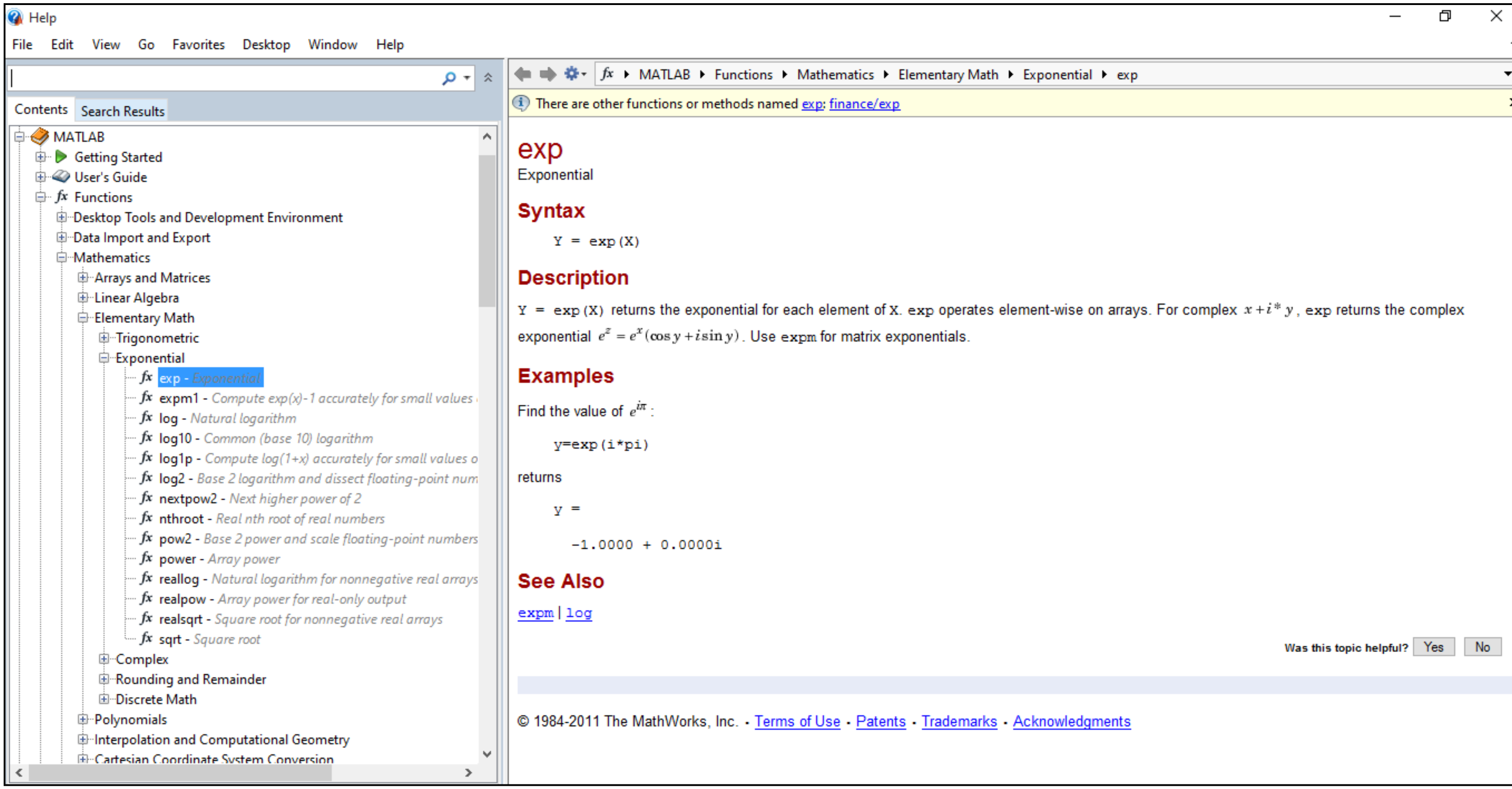
LOOKING UP

```
>> help exp
 EXP    Exponential.
    EXP(X) is the exponential of the elements of X, e to the X.
    For complex Z=X+i*Y, EXP(Z) = EXP(X)*(COS(Y)+i*SIN(Y)).

    See also expm1, log, log10, expm, expint.

    Overloaded methods:
       zpk/exp
       tf/exp
       codistributed/exp
       fints/exp
       xregcovariance/exp

    Reference page in Help browser
       doc exp
```

At the prompt, type help '*command*' or any keyword. Some suggestions may be given. Click doc file at the bottom to read the more elaborate document in a help file.

LOOKING UP

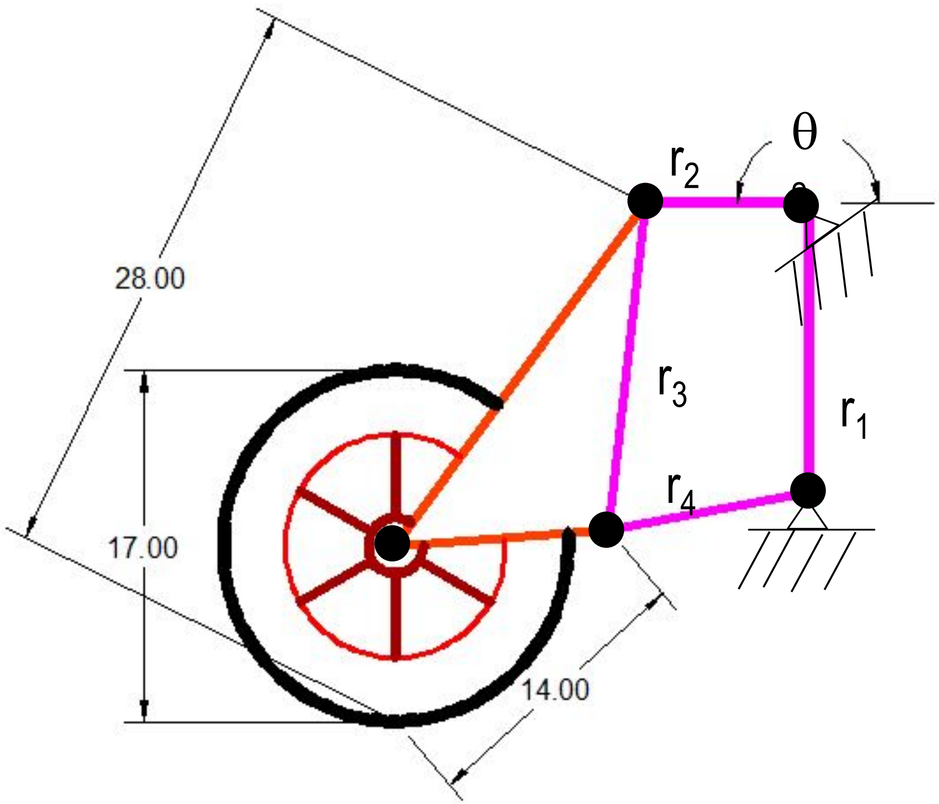
Hit F1 for help document

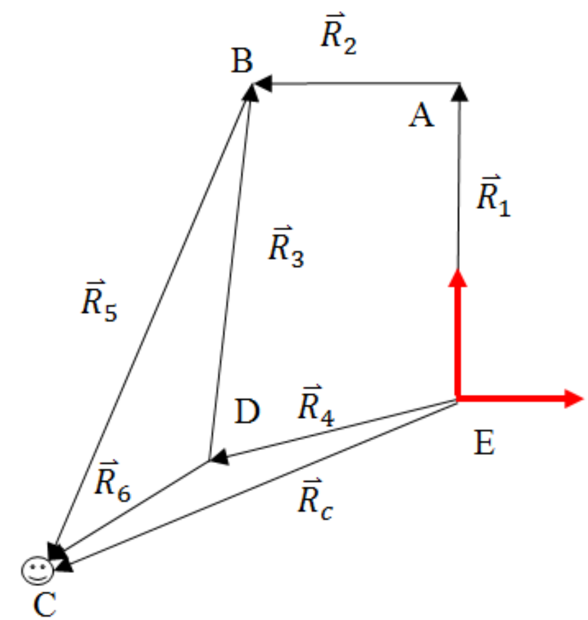


You may search for commands here. It is good to check so that your variable names is not the same as built-in ones. Otherwise, you may overwrite them.

EXAMPLE

It is a more general type of solution. Identify vector loop equations.





THE GIVEN

Fixed variables: $\alpha = 137.82°, \theta_1 = 90°, r_1, r_2, r_3, r_4, r_5, r_6$

Varying variables: $\theta_2 = [165°, 175°, \& \ 195°], \theta_3, \theta_4, \vec{R}_5, \theta_6, \vec{R}_c$

Loops:

(I) $\vec{R}_4 + \vec{R}_3 = \vec{R}_1 + \vec{R}_2$ (θ_3, θ_4) - unknown

(II) $\theta_6 = \theta_3 + \alpha$

(III) $\vec{R}_5 = -\vec{R}_3 + \vec{R}_6$

(IV) $\vec{R}_c = \vec{R}_4 + \vec{R}_6$

Known:

$\vec{R}_0 = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}, \vec{R}_1 = \begin{Bmatrix} 0 \\ 14 \end{Bmatrix}, \theta_2 = 195°$ (*This example considers this only*), $\theta_1 = 90°$ $r_2 = 8$, $r_3 = 16$, and $r_4 = 10$.

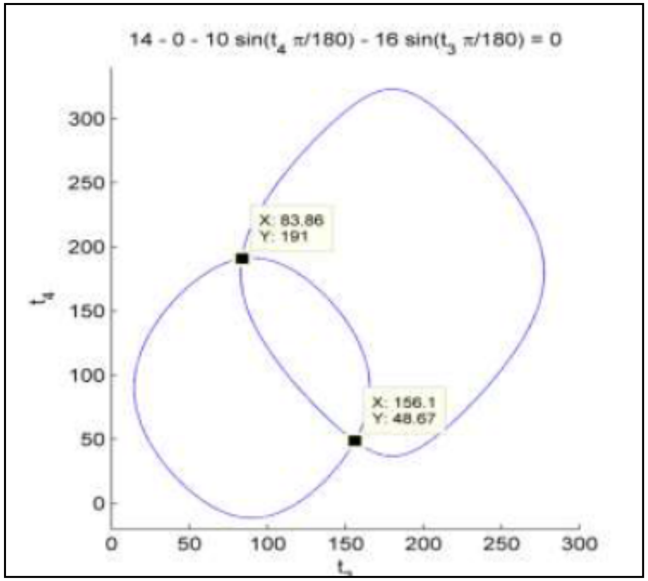
MAIN LOOP EQUATION

$$10\begin{Bmatrix}\cos(\theta_4)\\ \sin(\theta_4)\end{Bmatrix} + 16\begin{Bmatrix}\cos(\theta_3)\\ \sin(\theta_3)\end{Bmatrix} = \begin{Bmatrix}0\\ 14\end{Bmatrix} + 8\begin{Bmatrix}\cos(180^\circ)\\ \sin(180^\circ)\end{Bmatrix}$$

We will use *fsolve* to get theta3 and theta4. The initial guesses can be obtained from '*ezplotting*' the 2 equations. In Matlab's workspace, do this.

```
>> ezplot('0 - 8 - 10*cos(t4*pi/180) - 16*cos(t3*pi/180)', [0 300 -20 340])
```

```
>> hold on; ezplot('14 - 0 - 10*sin(t4*pi/180) - 16*sin(t3*pi/180)', [0 300 -20 340])
```



Some commands are in separate Toolboxes. If you do not install them, you could not use the commands.

CODING - SCRIPT

```
% MATLAB CODE FOR FOUR-BAR
% MECHANISM EXAMPLE – CAR SUSPENSION
% Clean up the workspace
clear; clc; close all

% Run fsolve to get theta3 and theta4
d2r = pi/180;
[Output1, f] = fsolve(@SolverHW16,[83*d2r 191*d2r]);
% Initial angles are from ezplot or just smart guess!

% Unpack our variables
theta3 = Output1(1);
theta4 = Output1(2);
theta3d = theta3/d2r
theta4d = theta4/d2r

% Specify the given joint/varying parameter(s)
R0 = [0; 0];

% Specify the physical/fixed parameters
theta2d = 170; % in degrees
theta2 = theta2d*d2r;
```

CODING - SCRIPT

```
% Locate the point of interest (POI)
r5 = 28; r6 = 14;
Alpha = 137.82; % degrees
theta6 = theta3 + Alpha*d2r;
theta6d = theta6/d2r;
R6 = r6*[cos(theta6); sin(theta6)];
R5 = -R3 + R6; % From the BCD triangle ...

P5 = P3 + R6; % THE POINT OF INTEREST
P6 = P5 - R5;
hold on
plot([P3(1), P5(1), P6(1)], [P3(2), P5(2), P6(2)], 'k-', 'linewidth', 3)
hold on
plot(P5(1), P5(2), 'rp', 'linewidth', 4)  % the star that shows POI

% Printing output: Optional...can be done in different ways too
disp('theta2        theta3       theta4        theta6')
OutRad = sprintf('%0.5g rad     %0.5g rad   %0.5g rad    %0.5g rad',theta2, theta3, theta4,
theta6);
disp(OutRad)
```

CODING - SCRIPT

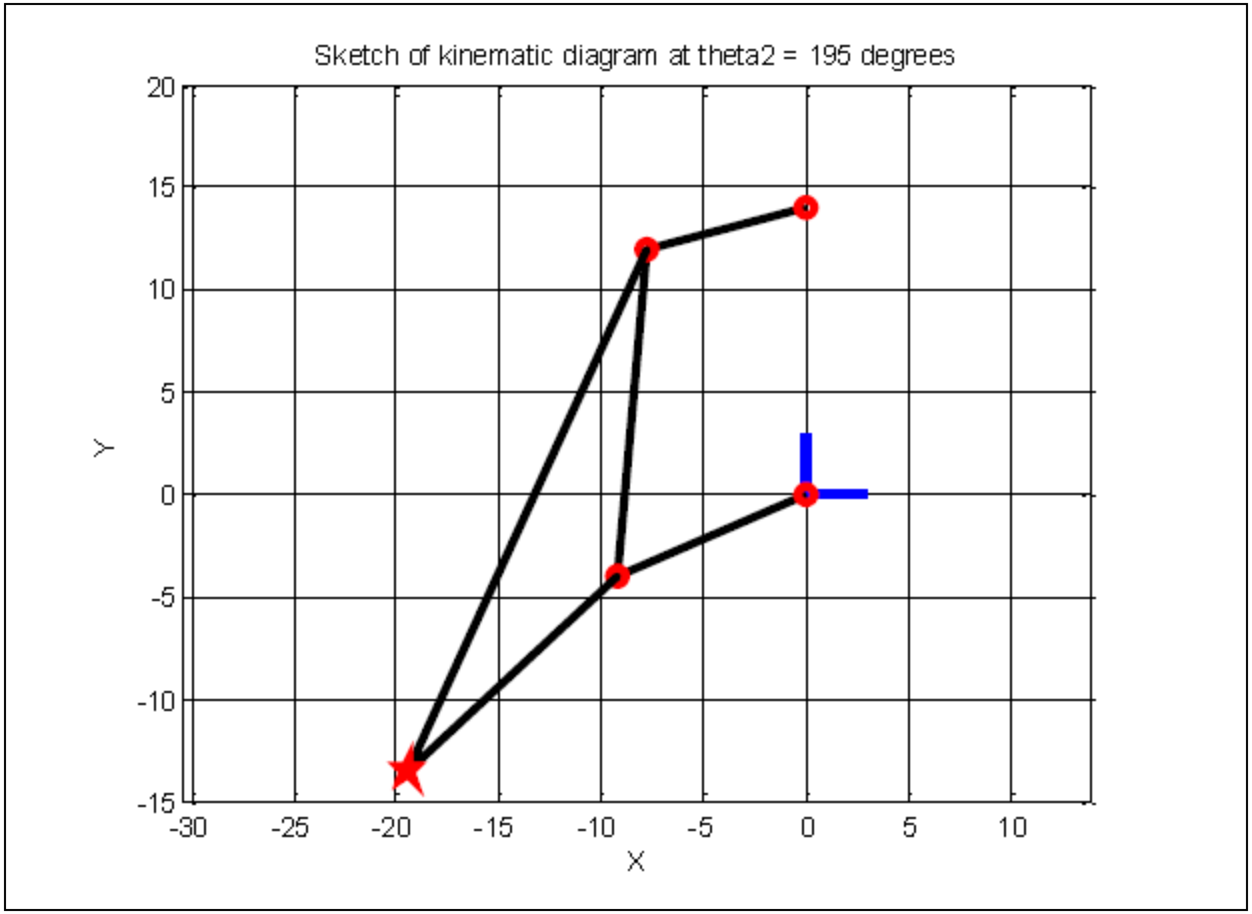
```
R1 = [0; 14];
R2 = 8*[cos(theta2); sin(theta2)];
r3 = 16;
r4 = 10;

% Build the unknown vectors
R3 = r3*[cos(theta3); sin(theta3)];
R4 = r4*[cos(theta4); sin(theta4)];

% Make the plot
P1 = R1;
P2 = R1 + R2;
P3 = P2 - R3;
P4 = P3 - R4;
plot([3 0 0], [0 0 3], 'b-', 'linewidth', 3)
hold on
plot([P1(1), P2(1), P3(1), P4(1)], [P1(2), P2(2), P3(2), P4(2)], ...
   'k-', 'linewidth', 3)
hold on
grid on
plot([P1(1), P2(1), P3(1), P4(1)], [P1(2), P2(2), P3(2), P4(2)], 'ro', 'linewidth', 3)
axis([-25 10 -15 20])

% Optional labeling stuff
sketch_title = sprintf('Sketch of kinematic diagram at theta2 = %d degrees',theta2d);
title(sketch_title)
xlabel('X')
ylabel('Y')
axis equal
```

CODING - FUNCTION

In a separate editor, create another m-file for the function.

```
Function [F] = SolverHW16(X)

% Unpack our variables
theta3 = X(1);
theta4 = X(2);


% Specify the given
R0 = [0; 0];
d2r = pi/180;
theta2 = 170*d2r; % Value here must be the same as in the main code!


R1 = [0; 14];
R2 = 8*[cos(theta2); sin(theta2)];
r3 = 16;
r4 = 10;

% Build the unknown vectors
R3 = r3*[cos(theta3); sin(theta3)];
R4 = r4*[cos(theta4); sin(theta4)];

% Identify the loop to solve where success when F = 0
F = R0 + R1 + R2 - R3 - R4; % R0 can also be left out since it is the origin.
```

PLOT OF THE OUTPUT

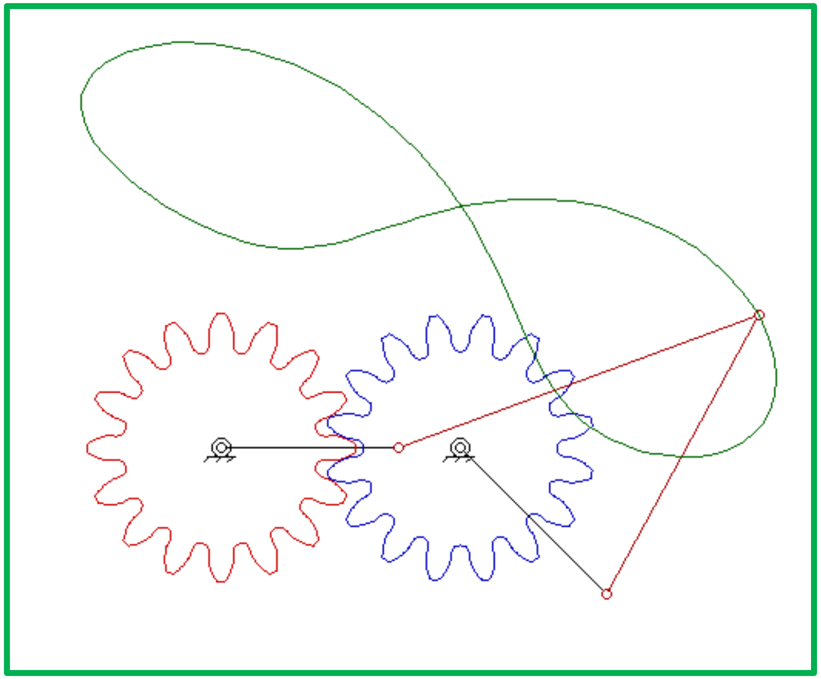


THANKS A BUNCH!

Main References:

[1] MATLAB Help File

[2] Myszka, David H., 2012. Machines and mechanism: applied kinematic analysis, 4th ed., Prentice Hall, New York.



Source:
https://en.wikipedia.org/wiki/Linkage_(mechanical)#/media/File:Gear-5-bar-right2.gif