

Introduction to Analytix/Cams

Welcome, and thank you for purchasing Analytix/Cams. This design and analysis software has the flexibility to allow you to start your design process with follower requirements, or with an existing cam profile.

Features Overview

Using Analytix/Cams, you can focus on optimizing your cam and follower design rather than spending time on tedious manual calculations.

Analytix/Cams also increases the reliability and performance of your cam and follower designs by providing the tools to analyze critical aspects of a design before physical prototyping or production. During the design process, Analytix/Cams immediately provides graphical and numerical analysis of critical data, such as cam profile, displacement, velocity, pressure angle, radius of curvature, acceleration and jerk.

Analytix/Cams supports convenient data input from external sources through simple copy and paste commands. You can also copy graphic illustrations in

the main window and paste them into other applications for generating reports and presentations.

Supported Cams and Followers

Analytix/Cams supports the following basic cam and follower types:

	Plate	Linear	Barrel
Flat/Reciprocating	x		
Flat/Oscillating	x		
Roller/Reciprocating	x	x	x
Roller/Oscillating	x	x	x

Plate cams with roller followers may be either external or internal. With linear and barrel cams, either the top or bottom cam surface may be modeled.

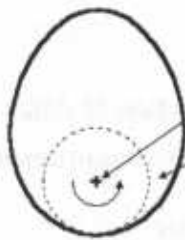
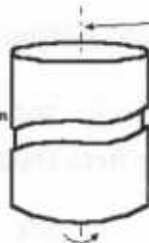


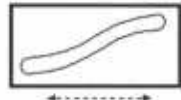
Plate Cam

Center of Rotation
Base Circle

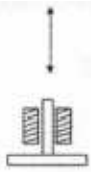


Barrel Cam

Axis of rotation



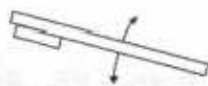
Linear Cam



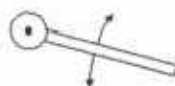
Flat Faced Follower
(reciprocating)



Roller Follower
(reciprocating)



Flat Faced Follower
(oscillating)



Roller Follower
(oscillating)

System Requirements

For the successful operation of Analytix/Cams, your system should meet these requirements:

- 386 PC or greater
- 2 MB of available RAM
- 2 MB of free hard disk space (7 additional MB required when also installing Analytix)
- Windows v3.1 or later

Before You Begin

Before you use Analytix/Cams for a design project, make sure you do the following:

- Decide whether your design approach is based on an existing cam, or based on follower requirements.
- Determine the general size of the cam and follower parameters, such as base circle radius, offset or follower radius.

This guide is written with the assumption that you have knowledge of mechanical design and cam/follower design principles in particular.

To learn more, consult the following recommended books, which contain informative chapters on cam/follower design:

- **"Design of Machinery,"** Robert L. Norton, McGraw Hill, 1992.
- **"Kinematics and Dynamics of Machinery,"** Charles E. Wilson, J. Peter Sadler, Walter J. Michels, Harper & Row.
- **"Theory of Machines & Mechanisms,"** J.E. Shigley & J.J. Uicker, McGraw Hill, 1980

About This Guide

This guide is divided into two sections: Tutorial and Reference.

Tutorial Section

- *Chapter 1* contains installation instructions.
- *Chapter 1* provides a brief overview of the Analytix/Cams main window.
- *Chapters 2 and 3* explain the two approaches to using Analytix/Cams:

Follower-to-Cam - You can quickly and easily create cam profiles based on existing follower requirements. In this mode, you can design a cam from scratch. Once you have designed the cam, you may want to investigate the follower motion resulting from using the cam with a different follower configuration. Any changes you make to the follower geometry parameters (such as follower offset, follower radius, and follower arm length) affect only the cam profile. Follower motion stays the same.

Cam-to-Follower - You have an existing cam and want to design or derive the follower motion. Using this design method you can input the cam's coordinates and manipulate parameters of the follower, such as follower offset, follower radius, and follower arm length. Follower kinematics are derived by the program.

- *Chapter 4* tells you how to integrate your design with Analytix. Analytix is machine design and simulation software with full animation, kinematics and dynamic analysis capabilities available from Saltire Software.

Reference Section

- *Chapter 5* explains the layout of the Analytix/Cams main window and describes in detail each of its components.

Chapter 1 - Quick Introduction to the Main Window

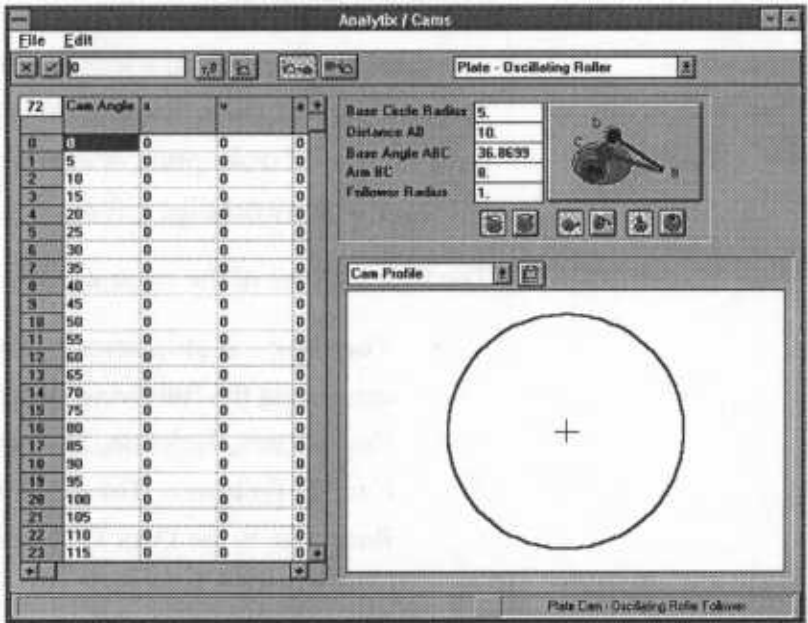
The Main Window

The Analytix/Cams main window contains four sections you will use to create your cam and follower designs. A brief description of each section is provided below. For more detailed information, see Chapter 5.

The four sections of the main window are:

- Tool Bar - A strip across the top of the window containing the following buttons: Polar Coordinates, Function, Follower-to-Cam and Cam-to-Follower. The other items in the Tool Bar relate to the Data Table and Cam/Follower Configuration area.
- Data Table - Provides numerical data on cam profile, displacement, velocity, acceleration and jerk (abbreviated in the Data Table as s, v, a, j). This also provides a way to enter a cam profile when in cam-to-follower mode.
- Cam/Follower Configuration area - Select the combination of cam and follower you are designing and define geometric and numeric input parameters in this area.

- Analysis area - Examine various graphs while defining the values and parameters for the cam and follower.



Chapter 2 - Follower-to-Cam Tutorial

Follower-to-Cam Example 1

This first example walks you through a design using the follower-to-cam approach. This means you can quickly and easily create cam profiles based on existing follower requirements.

In the follower-to-cam mode, use the Function window to piece together a desired follower motion.

Alternatively, you can paste values for follower displacement directly into the Data Table and Analytix/Cams will automatically derive the cam profile for you. Any modifications you make to the follower parameters, such as follower offset, follower radius, and follower arm length, will cause the cam profile to change, but will not affect your defined follower motion.

Example Requirements

In this example, you will design a plate cam with external reciprocating roller follower. Due to design constraints, such as clearances, the base circle radius is 5, the roller offset is .5 and the follower radius is 1. The cam rotates counter-clockwise and the follower offset is to the right.

- ⌘ Note: You may use any units of length (meters, inches, feet, etc.) as long as they are used consistently throughout the input process. Angles are always measured in degrees.

Between cam angle of 0 and 90 degrees the follower has a full cycloidal rise to a displacement of 1.5; between 90 and 180, a dwell and from 180 to 270 degrees a full cycloidal fall back to 0.

Setting Design Parameters

You can perform the following steps in any order, but you must define each before you begin the "Entering Data" section.

- 1 Click the Follower-to-Cam button in the Tool Bar.



- 2 In the drop-down menu in the Cam Configuration area (in the right corner), select the combination of cam and follower you are using. For this example, select Plate-Reciprocating Roller.



⌘ Note: As you select various options in this drop-down menu, the illustration below it changes to correspond to the type of cam/follower. The illustration does not change as you make other modifications in this configuration area.

3 Fill in the appropriate text box for the numeric input parameters:

Base Circle Radius = 5

Offset e = .5

Follower Radius = 1

4 Click the Update button (which appears as a graphical illustration to the right of the text boxes).

- Click the desired button for the appropriate geometric parameters:

Click the counter-clockwise button.



Click the offset to the right button.



Click the external follower button.



Now, you're ready to enter data.

Entering Data

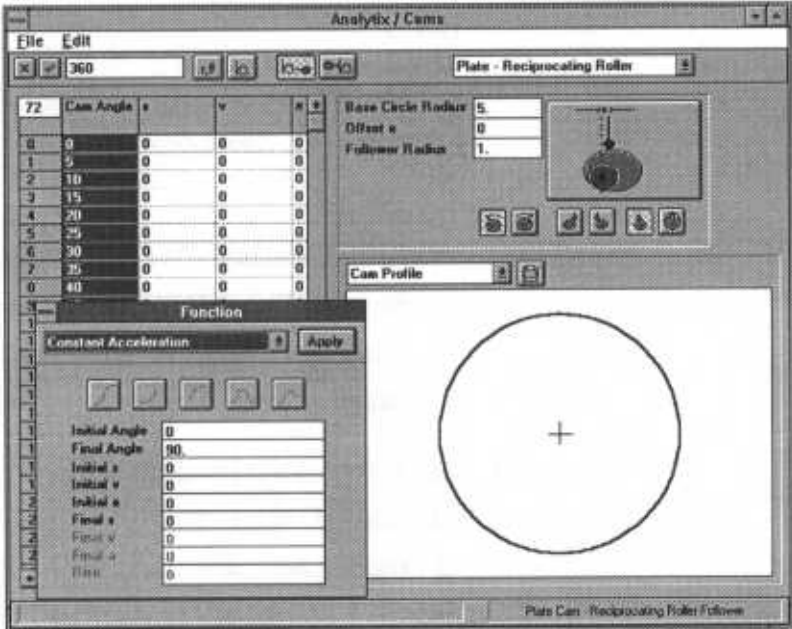
- 1 In the top left corner of the data table, type 72 to indicate the total number of data points to be entered. This will allow input every 5 degrees (i.e., $360 \text{ degrees}/72 = 5$) of cam angle.

For production designs, granularity of 1 degree or somewhat finer is more typical. Click in the Cam Angle column to update the degree increments in this column.

- 2 Using the mouse to click and drag, select cam angle 0 to 90 to indicate a range of data to be input. Alternatively, enter these values in Step 3.
- 3 Click the Function button.



The Function window appears.



Reposition this window by clicking and dragging its title bar so you can see various portions of the screen as you work.

- 4 In the Function window, select Cycloidal in the drop-down menu.
- 5 Verify that the Initial Angle and Final Angle text boxes are completed correctly.

This information is filled in automatically based on the data range you highlighted in Step 2.

6 Type 0 in the "Initial s" and 1.5 in the "Final s" text boxes.

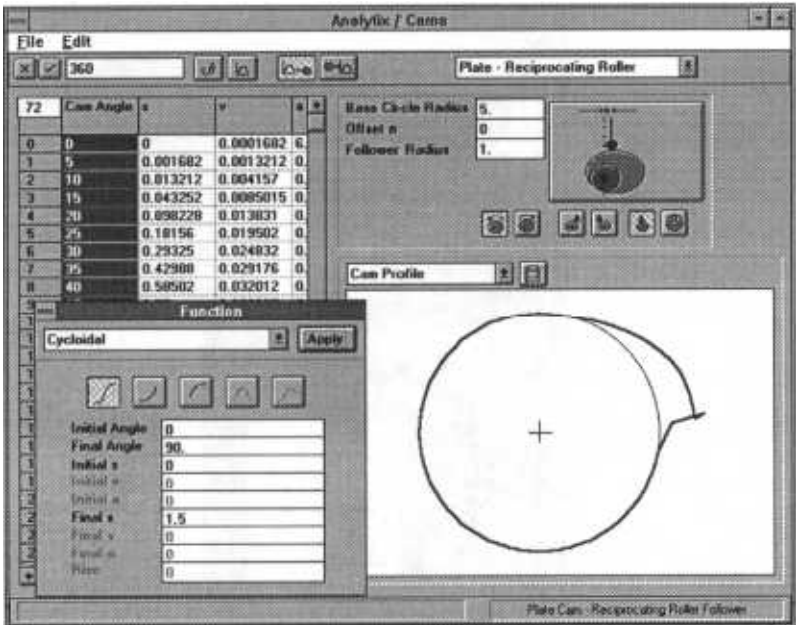
- **Oscillating**-When you're using oscillating followers, displacement units should be in degrees.
- **Reciprocating** - When you're using reciprocating followers, displacement units are consistent with base circle radius and follower radius.

7 At the top of the Function window, click the Full Rise button. (Only the curves available for this type of function are active.)



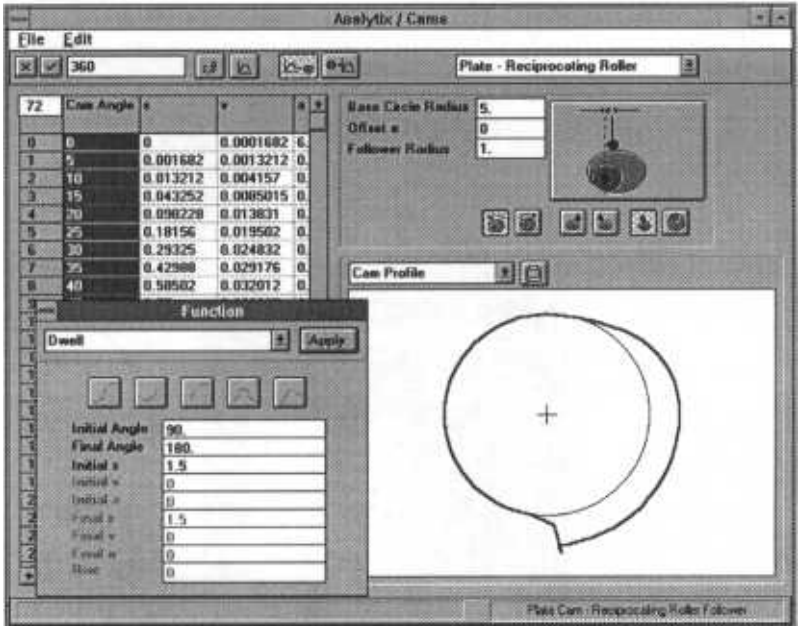
8 Click the Apply button in the Function window to calculate the data for the range you specified.

Your Function window should now look like the one below.

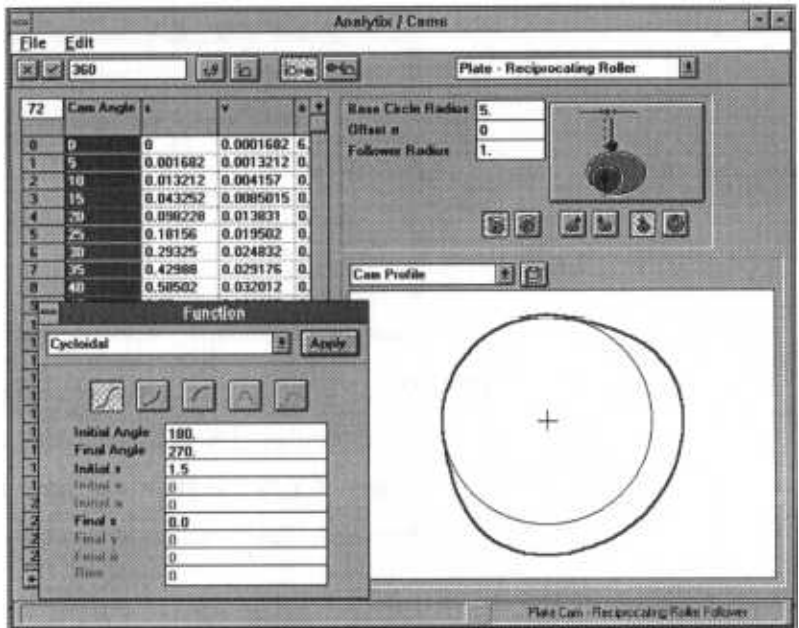


You can modify the data in the table by highlighting the appropriate cells and typing the new values in the Function window. Then, click Apply again.

- 9 Highlight the range of cam angles from 90 to 180 and select the Dwell in the Function window. (The first and final displacements are equal.) Type 1.5 in the "Initial s" field. Click Apply again.

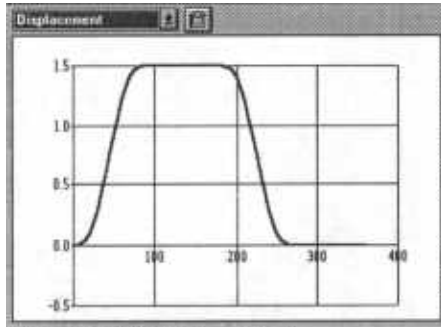


- Highlight the cam angle range 180 to 270 and select Cycloidal in the Function window. Type 0 in the "Final s" field. Click Apply again.



While defining the values and parameters for the cam and follower, you can examine various analysis graphs anytime in the Analysis area. See Chapter 5 for detailed information on the Analysis area.

At this point, your Analysis window with Displacement selected should look like the one below.



- 12 When you have finished your design, you can view the cam digitally in tabular format in the Data Table. Click the Polar to Cartesian button to toggle between these two coordinate systems.



- 13 Select Save in the Analytix/Cams File menu to use this data for use in the next chapter.

Follower-to-Cam Example 2

In this example, you will create a barrel cam, which drives a reciprocating follower at a constant velocity of 0.2 inches/degree between 50 and 200 degrees.

Between 0 and 50 you will see a half rise cycloidal function to smoothly blend in to the constant velocity portion of the cam. Between 200 and 330 degrees, you will use a 3-4-5 polynomial to bring the displacement back to 0. If you have been working on the previous example, select New in the File menu to start.

Setting Design Parameters

You can perform the following steps in any order, but you must define each before you begin the "Entering Data" section.

- 1 Click the Follower-to-Cam button in the Tool Bar.



- 2 In the drop-down menu in the Cam Configuration area (in the upper right corner), select the combination of cam and follower you are using. For this example, select Barrel-Reciprocating Follower.

⌘ Note: As you select various options in this drop-down menu, the illustration below it changes to correspond to the type of cam/follower. The illustration does not change as you make other modifications in this configuration area.

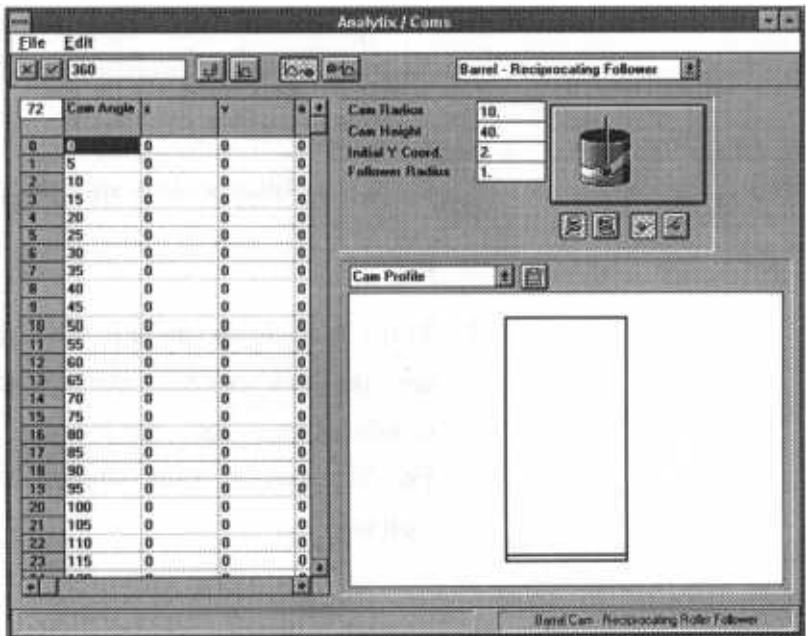
3 Fill in the appropriate text box for the numeric input parameters:

Cam Radius = 10

Cam Height = 40

Initial Y Coord. = 2

Follower Radius = 1



- 4 Click the Update button (which appears as a graphical illustration to the right of the text boxes).

Now, you're ready to enter data.

Entering Data

- 1 In the top left corner of the table, type 72 to indicate the total number of data points to be entered. This will allow input every 5 degrees of cam angle (i.e., $360 \text{ degrees}/72 = 5$).
- 2 Using the mouse to click and drag, select cells with cam angle ranging from 0 to 50 to indicate a range of data to be input. Alternatively, enter these values in Step 3.
- 3 Click the Function button.



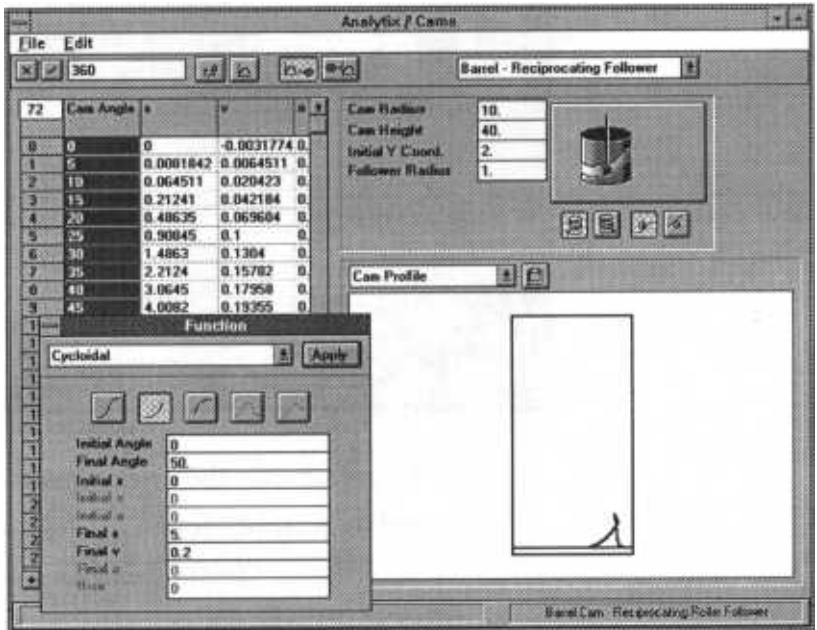
The Function window appears.

- 4 In the Function window, select Cycloidal in the drop-down menu.
 - 5 Click the Initial Half Rise button.
- 6 Verify that the Initial Angle and Final Angle text boxes are completed correctly.

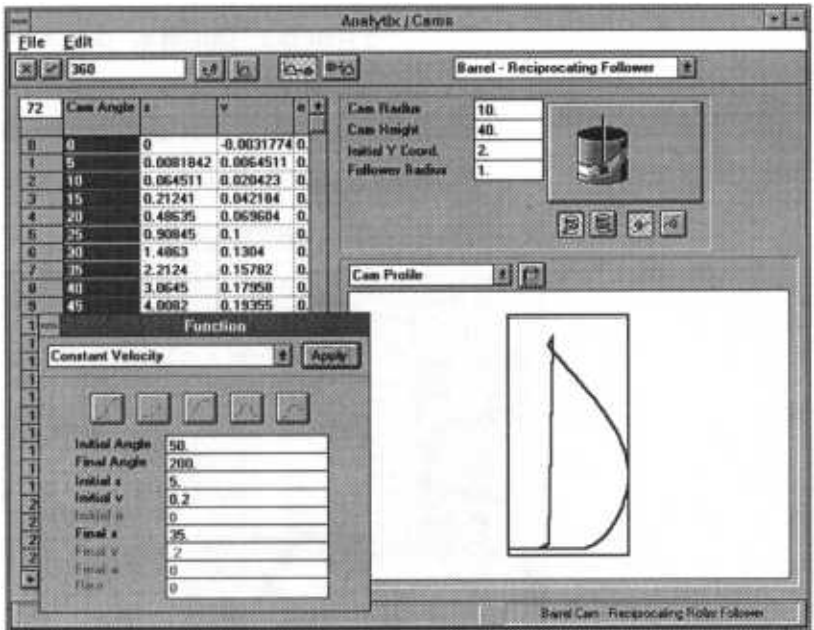


This information is filled in automatically based on the data range you highlighted in Step 2.

- 7 Type 0 in the "Initial s," 5 in the "Final s" and 0.2 in the "Final v" text boxes to match the constant velocity. Analytix/Cams automatically supplies the final value for displacement. Click Apply.



- 8 In the Data Table, use the mouse to select cells with cam angle ranging from 50 through 200. In the Function window's drop-down menu, select Constant Velocity. Verify 50 in the Initial Angle and 200 in the Final Angle text boxes. Type 5 in the "Initial s" text box and .2 in the "Initial v" text box. Analytix/Cams automatically supplies a value of 35 for the final displacement. Click Apply.



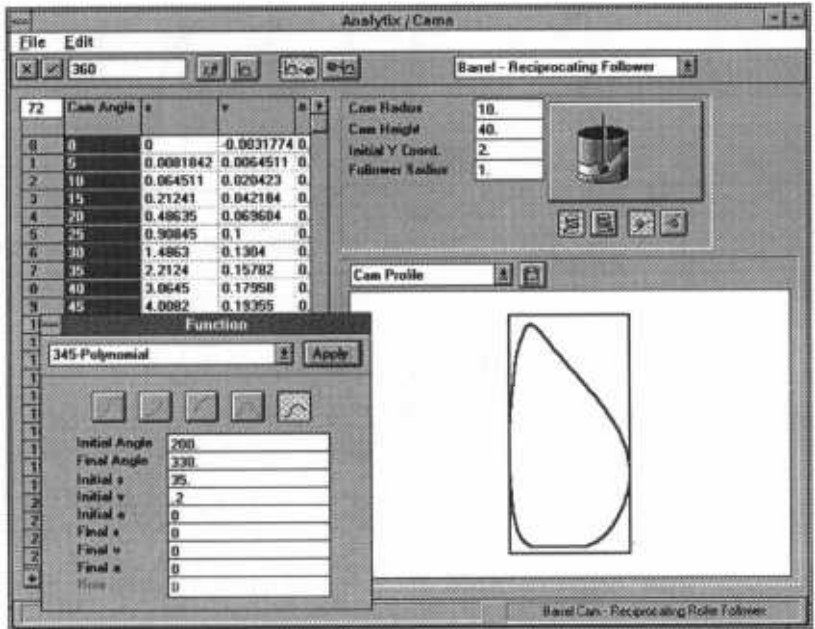
- 9 Finally, create the final segment using a 3-4-5 polynomial between 200 degrees and 330 degrees of cam angle. (Select these cells in the Data Table or type the range of degrees in the Function window.)

This time, in the Function window specify the following:

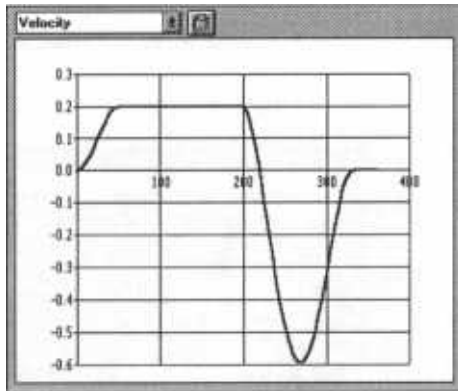
- "Initial s" is 35 to match the final displacement from the constant velocity segment.
- The "Initial v" is .2 to match the constant velocity segment.
- "Initial a" is 0.

- "Final s," "Final v," and "Final a" are all 0.

10 Click Apply.



At this point, your Analysis window with Velocity selected should look like the one below.



- 11 To save your example for future use, select Save in the File menu.

Chapter 3 - Cam-to-Follower Tutorial

In some cases, an existing cam must be modified slightly, or follower motion redesigned or analyzed. Analytix/Cams facilitates this task.

The example below assumes you have manufactured the cam you designed in Chapter 2. Now you want to redesign the follower system to meet new requirements and see the effect on the follower motion.

In the cam-to-follower mode, you can change the x and y coordinates. Other than this, any modifications you make to the cam/follower parameters will cause the follower motion to change, but will not affect your defined cam.

If you have not saved the previous two examples, find these examples on the Analytix/Cams disk as *ex1.cam* and *ex2.cam*.

Example Requirements

In this example, you will use the cam profile data generated in example 1 of Chapter 2. You can also use your own data by typing it into the Data Table, copying data from another source and pasting it into the Data Table, or reading in a file containing the cam profile.

For example, you may have x,y data in a text file that may have come from a computer-aided manufacturing software package, or from a cam measuring instrument.

Setting Design Parameters

You can perform the following steps in any order, but you must define each before you begin the "Entering Data" section.

- 1 If you are using the data you saved in Chapter 2, select Open in the Analytix/Cams File menu to open that file.
- 2 Click the Cam-to-Follower button at the top of the window. (Note that the cam coordinate columns now appear first in the Data Table.) If you are using the data you save in Chapter 2, go to Step 3 under "Entering Data."



- 3 In the Cam/Follower Configuration area in the top right corner of the window, select the appropriate cam and follower combination of cam you are considering.



Note: As you select various options in this pop-up menu, the illustration below it changes to correspond to the type of cam and follower combination.

- 4 Define the parameters of the cam and follower by completing the text boxes in the Cam/Follower Configuration area.
- 5 Click the appropriate geometric parameter buttons.
- 6 Click the Polar Coordinates button to specify input coordinate system.



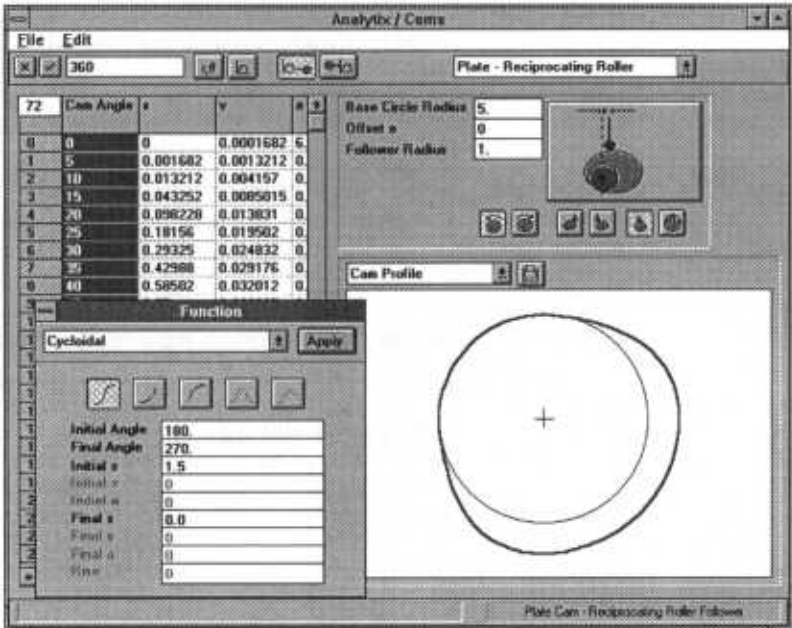
Now, you're ready to enter data.

- ⌘ Note: If you are using the file loaded in the first example, the data will already exist. Go to Step 3 below.

Entering Data

- 1 In the top left corner of the table, type the total number of data points to be entered. Click in the Cam Angle column to update the degree increments in this column.
 - 2 Add data to the Data Table in three ways:
 - Enter data manually by selecting a cell and typing data into that cell.
 - Copy information from another source (such as a spreadsheet) and paste it into the Data Table.
 - Open an ASCII file (either comma- or tab-delimited).
- ⌘ Note: If you're copying and pasting information, make sure the source file is free of any extra characters, such as commas or other punctuation. The x,y or r,θ data must be in tab-delimited format with a return at the end of each line. This is the default when copying and pasting from a spreadsheet program. You need to highlight the region of the Data Table you want to paste information into before pasting.

The appropriate graphical information for the data you entered appears in the Analysis area.



3 You can fine-tune cam coordinates by:

- modifying the data in the Data Table and viewing the resulting graphics in the Analysis area.

OR

- modifying parameters in the Cam/Follower Configuration area.

Modifying follower parameters does not alter the cam profile in this mode. It only modifies the follower kinematics.

Chapter 4 - Integrating Cams Into Analytix

- ⌘ Note: If you do not yet own Analytix, contact Saltire Software for more information.

This chapter explains how to integrate your cam designs into Analytix and provides two examples to help you master the process. First, you should have a basic understanding of how to use Analytix. Refer to the Analytix Reference Manual as needed to use the product.

In the two design approaches discussed in this guide, you may be interested in analyzing the cam/follower in the context of a larger mechanism. This may include linkages, springs, dampers, cam "float," etc. To do this mechanical systems analysis and simulation, use Analytix v3.2 or later, which includes integration features with Analytix/Cams.

You can import the cam profiles into Analytix and actually animate the mechanism, driven by the cam. Also, you can analyze torque on the cam shaft, motion paths of attached machinery, forces on pins, clearances, tolerances and so on.

Detailed instructions for using Analytix are found in the Analytix Reference Manual. The information below describes how to add a cam design to Analytix.

To add a cam to Analytix:

- 1 Open Analytix v3.2 or higher.
- 2 Select Add Cam in the Analysis menu.

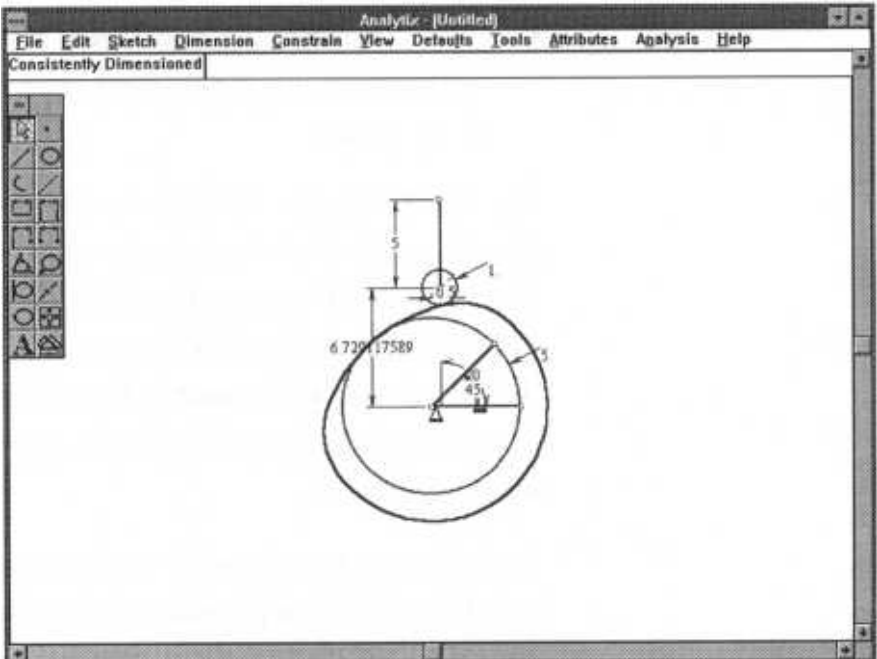
Analytix/Cams opens.

- 3 Open an existing cam file or follow the instructions in the previous chapters to create a cam.
- 4 Select the desired button for Follower-to-Cam or Cam-to-Follower.

- If you select the Follower-to-Cam mode, any changes you make in Analytix to follower parameters (such as follower arm length, follower offset, etc.) will modify the cam profile. The follower kinematics are preserved.
- If you select the Cam-to-Follower mode, changing follower parameters in Analytix will preserve the same cam profile and adjust the follower motion.

- 5 You can return to Analytix/Cams and make more extensive modifications to the cam by double-clicking the cam profile.
- 6 Exit Analytix/Cams and return to Analytix.

You should see your cam configuration in the Analytix window. The cam and follower elements are highlighted. (The default color is **red**.)



- 7 To rotate the cam/follower object:
 - Select the geometrical cam/follower objects to be rotated. (Dimensions on their own are not rotated, but follow the geometry.) These are already highlighted.
 - Select Rotate in the View menu.
 - Click on the center of the rotation (such as the center of the cam or the follower).

- Position the cursor over a part of the cam/follower to be rotated (away from the center of rotation).
- Click and drag the cam/follower. When the cam/follower is correctly positioned, release the mouse button.

You can change cam and follower dimensions directly within Analytix with appropriate changes in cam shape or follower configuration. When you add a cam to a consistently dimensioned Analytix session, the cam will appear in Analytix to scale. This may require that you zoom out to view the whole picture.

With all cams, two important dimensions are specified in the Analytix model: the cam input dimension and the follower displacement dimension.

- For plate and barrel cams, the input dimension is an angle.
- For linear cams, the input dimension is a distance.
- For oscillating followers, the follower displacement dimension is an angle.

- For reciprocating followers, the follower displacement dimension is a distance.

Other dimensions in the model may represent follower parameters.

Cams in Analytix

The graphics below represent the eight cam types as they appear in Analytix.

Plate Cam - Reciprocating Flat Face Follower

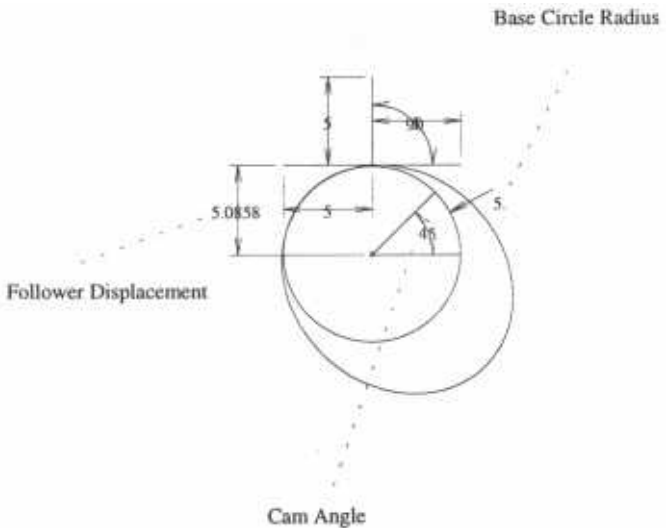


Plate Cam - Reciprocating Roller Follower

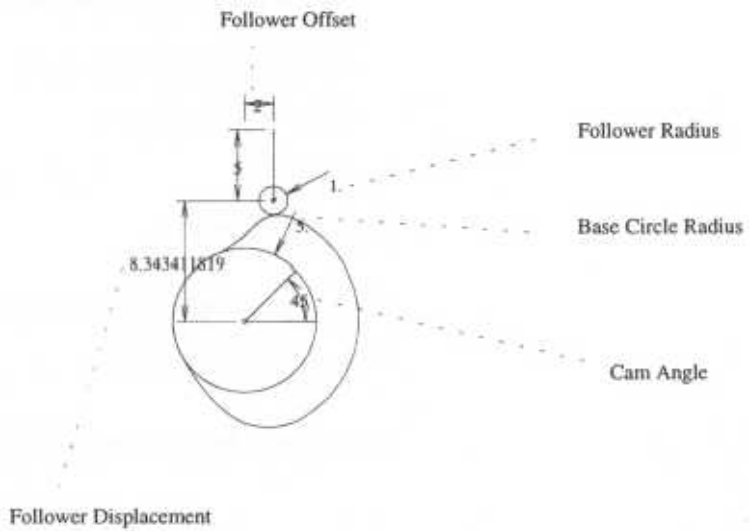


Plate Cam - Oscillating Flat Face Follower

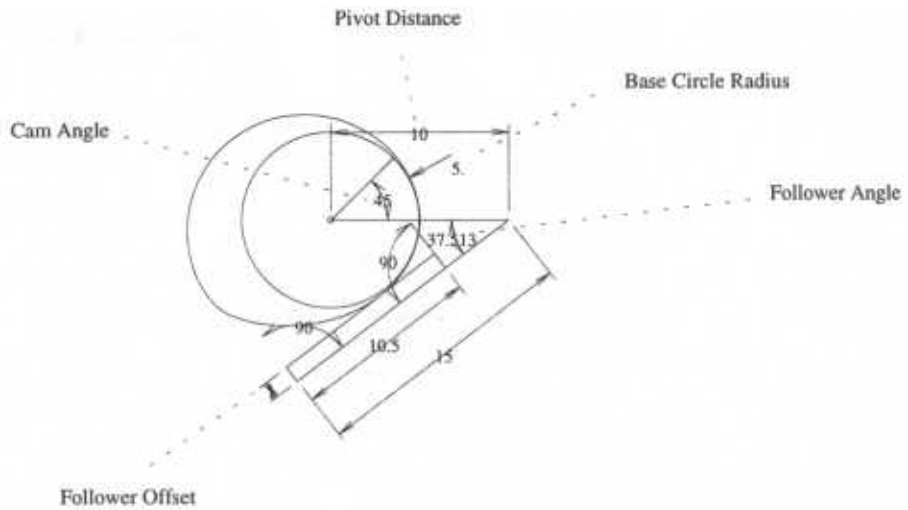
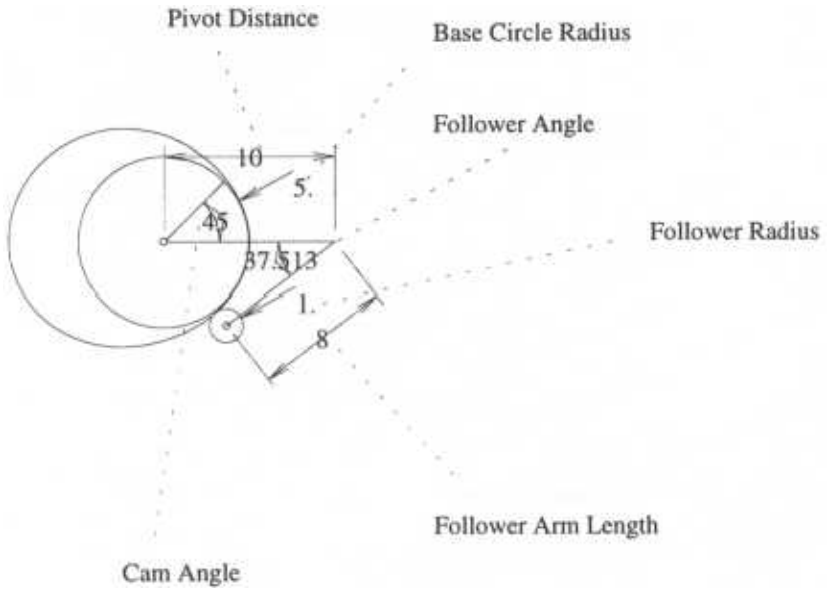
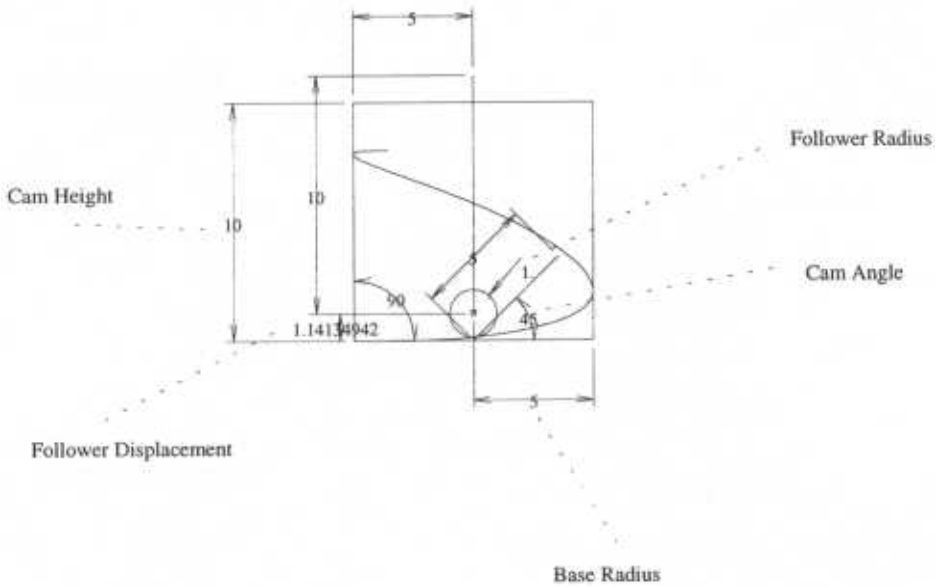


Plate Cam - Oscillating Roller Follower



Barrel Cam - Reciprocating Follower



Integration With Analytix - Example 1

Now that you've gone through the tutorial that explains how to integrate your cam into Analytix, you're ready to plug in example data.

In this example, you'll see how to derive camshaft torque for a cam in Analytix. Also, you'll learn how to determine if and when the follower will lift or "float" from the cam.

First, create the cam by following these steps:

- 1 In Analytix, select Add Cam in the File menu.

Analytix/Cams opens.

- 2 Click the Follower-to-Cam button in the Tool Bar.



- 3 In the drop-down menu in the Cam Configuration area, select Plate-Oscillating Flat-Face Follower.
- 4 Fill in the appropriate text box for the numeric input parameters:

Base Circle Radius = 5

Pivot AB = 10

Base Angle ABC = 30

Offset = 0

- 5 Click the Update button (which appears as a graphical illustration to the right of the text boxes).

Now, you're ready to enter data.

Entering Data

- 1 In the top left corner of the table, type 72 to indicate the total number of data points to be entered. This will allow input every 5 degrees (i.e., $360 \text{ degrees} / 72 = 5$).
- 2 Using the mouse to click and drag, select cells 0 to 240 to indicate a range of data to be input. Alternatively, enter these values in Step 3.
- 3 Click the Function button.



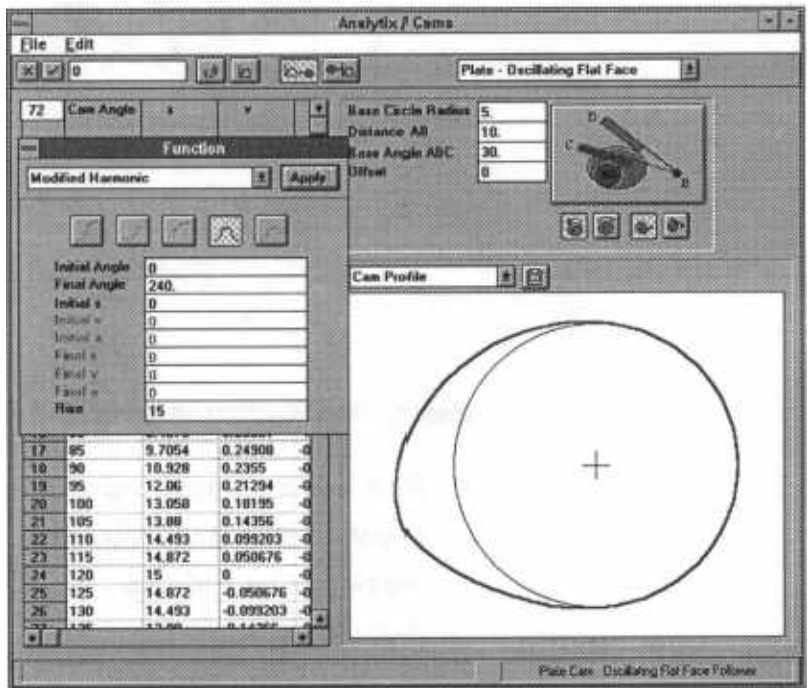
The Function window appears.

- 4 In the Function window, select Modified Harmonic in the drop-down menu.
- 5 Click the Single Dwell button.



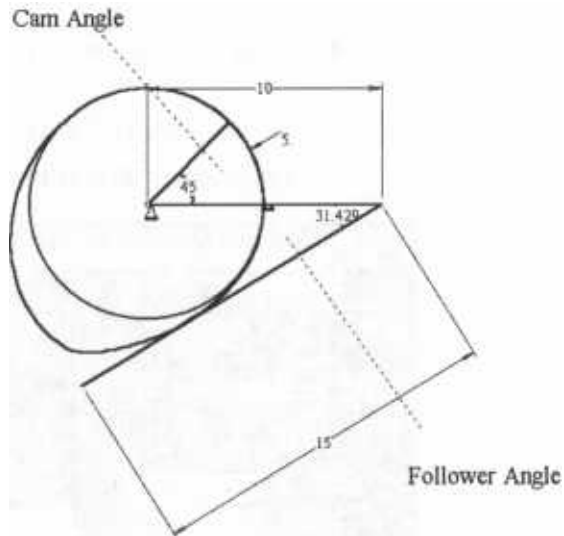
- 6 Verify that the Initial Angle and Final Angle text boxes are completed correctly. Also, make sure "Initial s" is set to 0.
- 7 Type 15 in the Rise text box.

Your Analytix/Cams window with all settings established should look like the window below:



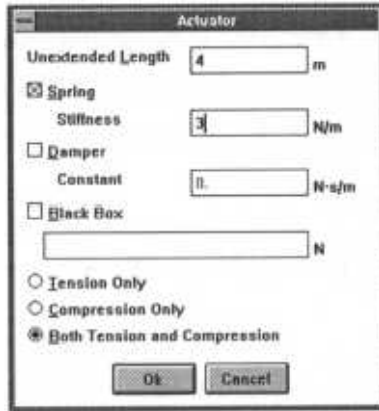
- 8 Click Apply in the Function window.
- 9 Close Analytix/Cams and return to Analytix.

When placed into Analytix, this is how the cam and follower system appears:

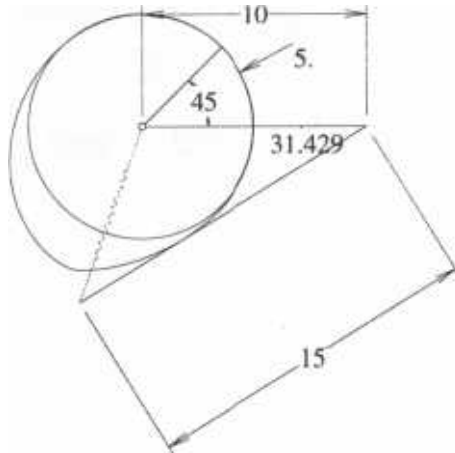


Making Modifications in Analytix

- 1 First, add a spring between the center of the cam and the end of the follower arm. To do this, select the two points and then use the Analysis/Add Actuator menu.
- 2 Set the spring unextended length to 4 and the stiffness to 3. Deselect Damper and Black Box. Select both Tension and Compression. Click OK.



- 3 Complete the model by adding a moment of inertia of 10 to the follower arm. To do this, double-click the line representing the follower and fill in the Inertia text box. Click OK.

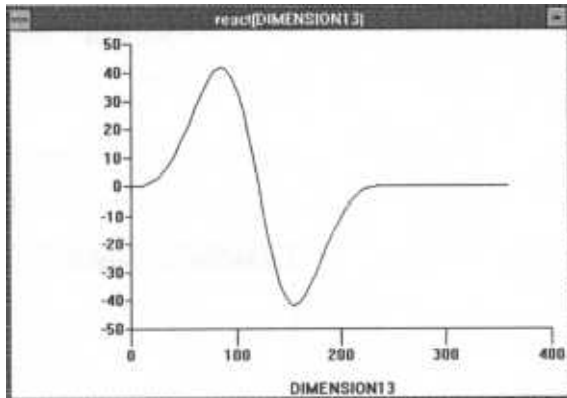


- ⌘ **Note:** In a more realistic model, you would also create a point for the center of mass of the follower arm. This example assumes the center of mass is at the pivot point.

4 Camshaft Torque:

The cam shaft torque is represented by the reaction torque in the cam angle (45 degrees in the above diagram.) So, to graph the camshaft torque, graph the reaction on this angle.

Field	Value
Parameter t	DIMENSION13
X axis variable	
Y axis variable	react[DIMENSION13]
Initial t	0
Final t	360
t increment	5



This reaction is positive (compression) during the first 120 degrees of the motion (where the cam is pushing against the spring) and negative in the next 120 degrees where the cam is being pushed by the follower arm.

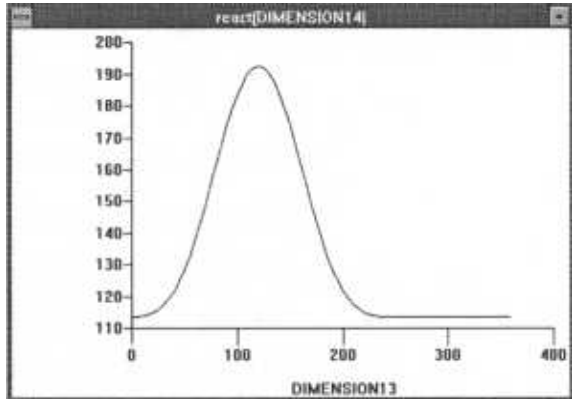
5 Follower Lift:

To detect follower lift or "float," examine the reaction torque in the follower angle. This torque should stay in compression if the follower stays in contact with the cam. The faster the cam is rotating, the greater the inertia forces due to the acceleration of the follower arm and therefore the greater the danger of the follower lift.

In this example, you will find the maximum angular velocity at which this cam can be driven without float occurring.

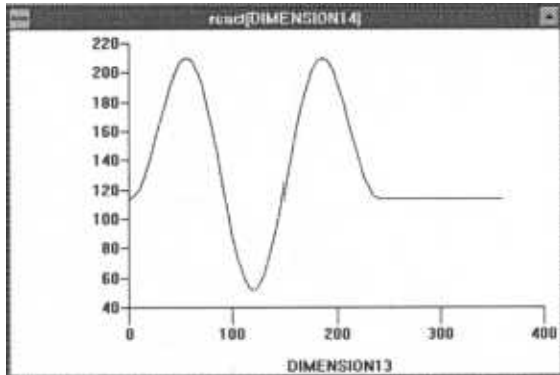
First, double-click the cam angle and set a unit angular velocity.

The graph of the reaction on the follower angle against cam angle looks like the window below:



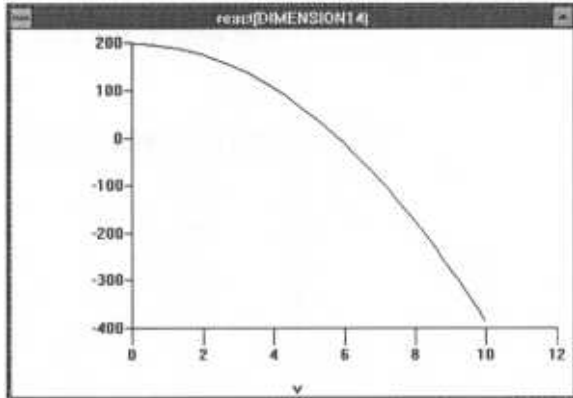
This remains positive (compression) and therefore, float does not occur.

Look now at the case where the cam velocity is 6 rad/sec:

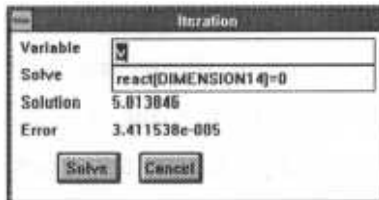


The reaction is still all positive, but you see that it dips strongly at 120 degrees. To find the velocity where lift occurs, set the cam velocity to have a variable value (v in this model), and set the cam angle to 120 degrees to match the worse case.

Graph the follower angle reaction against velocity for this worse case:



Read a solution off the graph, or alternatively, use the Univariate Iteration tool to derive an accurate value for v .



Hence, the maximum speed for this cam and follower system without follower float is 5.81 rad/sec. You can then do "What if" analysis to vary the geometry or the spring to optimize your design.

Integration With Analytix - Example 2

In this example, you learn how to build a model with two cams working from the same axis, driving a linkage.

Use the cam of the previous example to drive the motion of an oscillating arm, and add a second cam with a reciprocating roller follower.

- 1 Within Analytix, start with the previous model, but increase the length of the follower arm to 25.
- 2 Analytix always locates its cams at the origin. To avoid initial confusion, move the first cam away from the origin before adding another cam. To do this, select the existing model and use the View/Move menu option.
- 3 Add a second cam by selecting Add Cam in the Analytix File menu.

Analytix/Cams opens.

- 4 Click the Follower-to-Cam button in the Tool Bar.



- 5 In the drop-down menu in the Cam Configuration area, select Plate-Reciprocating Roller.

- 6 Fill in the appropriate text box for the numeric input parameters:

Base Circle Radius = 5

Offset $e = 0$

Follower Radius = 1

- 7 Click the Update button (which appears as a graphical illustration to the right of the text boxes).

Now, you're ready to enter data.

Entering Data

- 1 In the top left corner of the table, type 72 to indicate the total number of data points to be entered. This will allow input every 5 degrees (i.e., $360 \text{ degrees} / 72 = 5$).
- 2 Using the mouse to click and drag, select cells with cam angle 0 to 240 to indicate a range of data to be input. Alternatively, enter these values in Step 3.
- 3 Click the Function button.



The Function window appears.

4 In the Function window, select Modified Harmonic in the drop-down menu.

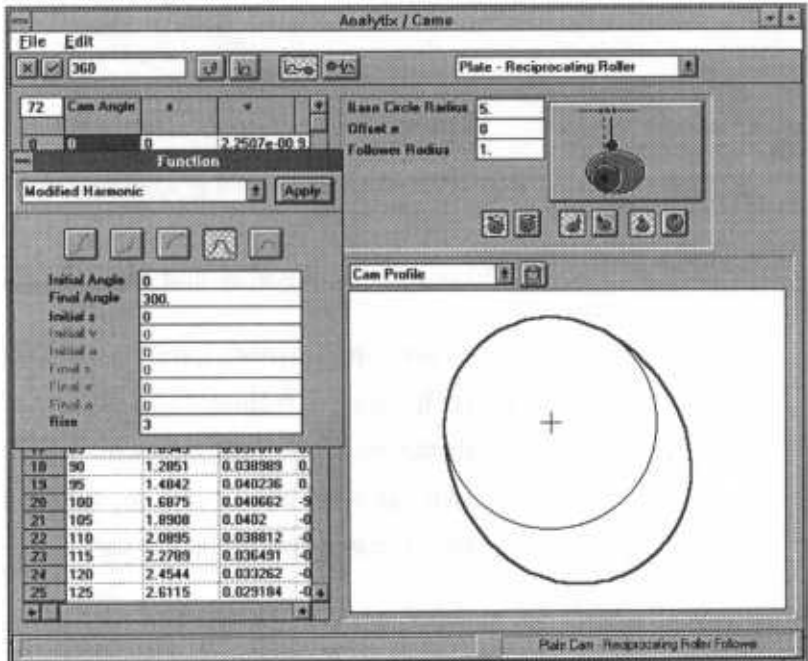
5 Click the Single Dwell button.



6 Verify that the Initial Angle and Final Angle text boxes are completed correctly.

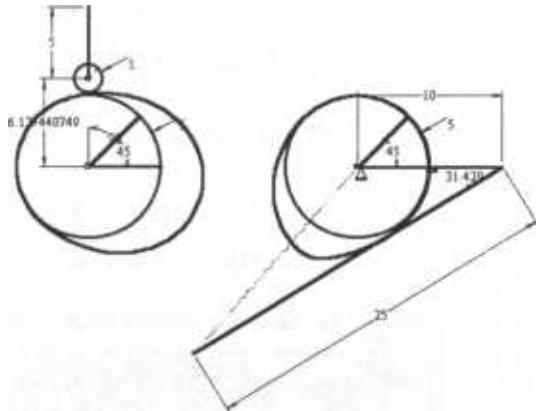
7 Type 3 in the Rise text box.

Your Analytix/Cams window with all settings established should look like the window below:



- 8 Click Apply in the Function window.
- 9 Close Analytix/Cams and return to Analytix.

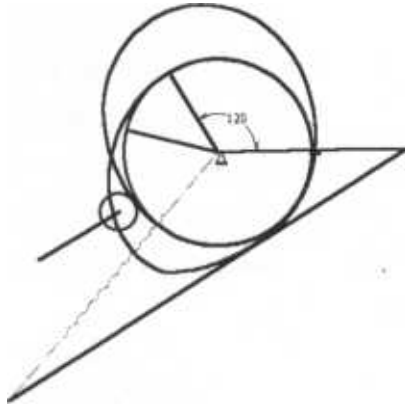
When placed into Analytix, this is how the cam and follower system appears:



Note that the model is under dimensioned. To be consistently dimensioned, you need to dimension the relative position and angle of the two cams.

In fact, in this model, the line of the action of the reciprocating follower should be parallel to the base direction of the follower arm. The base lines for the two cams should be 120 degrees apart. Also, the cam centers should be the same.

First, rotate and move the second cam into approximately the correct location and orientation.



The model should be consistently dimensioned.

Driving Both Cams

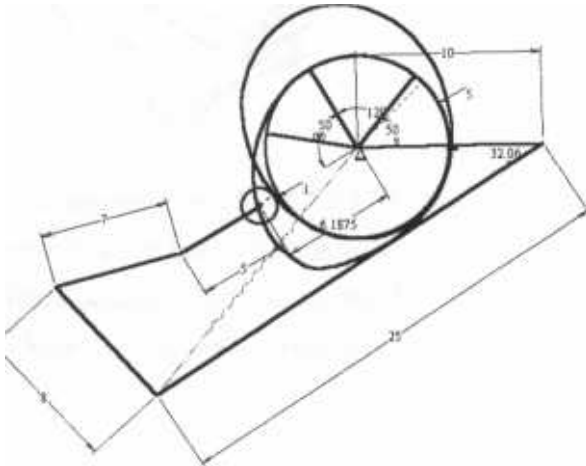
Now, you see two cams, sitting on the same axis. However, they each have their own driving angle. To drive both cams together, link each angle to a common parameter (in our case, parameter t).

- 1 First, give an initial value: In the Analytix Calculator, set $t=50$.
- 2 Double-click the first cam's cam angle and set its value to t .
- 3 Double-click the second cam's angle and set its value to t .

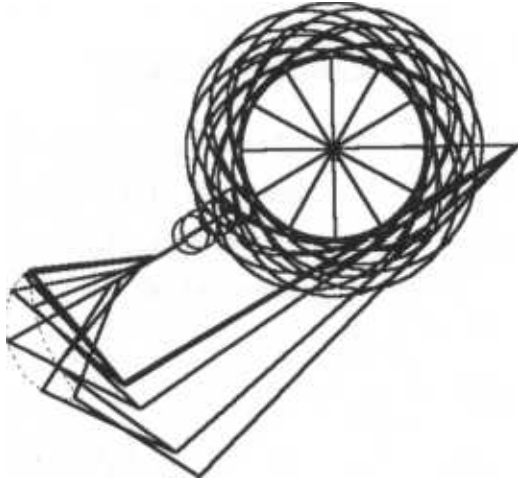
- 4 Now, animate the double cam by setting the parameter of the animation to t and let t vary from 0 to 360.

Creating a Linkage

- 1 Add and dimension a simple linkage between the end points of the two followers. The linkage consists of two lines drawn and dimensioned as shown below.



- 2 Now, if you animate the cams as described above, you see the linkage move.



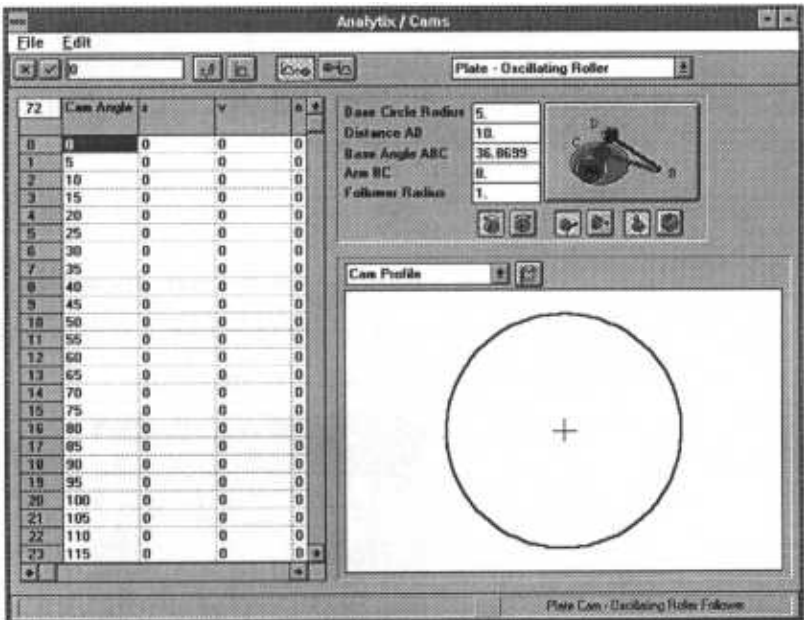
- ⌘ Note: The above example shows how cams may be combined in Analytix and interlocking mechanisms built on the cam models. Realistic models of greater complexity may be built applying the same principles.

Chapter 5 - Detailed Description of the Main Window

Below is the Analytix/Cams main window, which is visible at all times.

Four main sections appear in the main window:

- Tool Bar
- Data Table
- Cam/Follower Configuration area
- Analysis area



Tool Bar

The Tool Bar contains four independent buttons.



The items on either side of these four buttons are related to the Data Table and the Cam/Follower Configuration area. These items are described later.

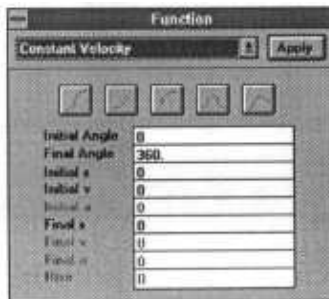
- **Polar Coordinates Button:** This is a toggle that selects whether the cam profile is in Cartesian or polar coordinates.



- **Function Button:** Click this button to see the Function window for selecting cam profile curve types.



- **Function Window:** Allows you to choose the type of curve between points when in the follower-to-cam mode



The buttons at the top of the Function window are:

Full Rise



First Half Rise



Second Half Rise



Single Dwell



Polynomial Spline



- Follower-to-Cam Button: Click to indicate your design approach is follower-to-cam.



- Cam-to-Follower Button: Click to indicate your design approach is cam-to-follower.



Data Table

The Data Table, shown below, provides numerical data on displacement, velocity, acceleration and jerk (abbreviated in the Data Table as s, v, a, j). You can enter x and y or r and ϕ data manually into each cell. You can cut, copy and paste from a text editor, spreadsheet or other Windows data, or you can have the cam profile data synthesized by the application, using the Function window and the Cam/Follower Configuration options.

72	Cam Angle	s	v	a	j
0	0	0	0	0	0
1	5	0	0	0	0
2	10	0	0	0	0
3	15	0	0	0	0
4	20	0	0	0	0
5	25	0	0	0	0
6	30	0	0	0	0
7	35	0	0	0	0
8	40	0	0	0	0
9	45	0	0	0	0
10	50	0	0	0	0
11	55	0	0	0	0
12	60	0	0	0	0
13	65	0	0	0	0
14	70	0	0	0	0
15	75	0	0	0	0
16	80	0	0	0	0
17	85	0	0	0	0
18	90	0	0	0	0
19	95	0	0	0	0
20	100	0	0	0	0
21	105	0	0	0	0
22	110	0	0	0	0
23	115	0	0	0	0
24	120	0	0	0	0

The Data Table contains vertical and horizontal scroll bars for viewing data. The columns in the table allow you to expand or reduce the width of a column by

clicking and dragging the horizontal bar separating each column.

In the upper left corner of the table, you can specify the total number of data points to be entered. These data points appear in the far left column and represent the degree values for which cam or follower data will be entered. A greater number of data points allows for a finer breakdown of degree intervals.

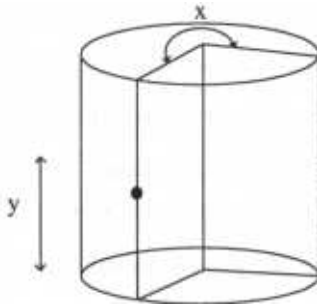
Studies of CNC fabrication by Norton and others indicate that one half to one degree increments are adequate for the design phase, even for high-speed cams. Finer increments are not practical to manufacture, even with CNC machine tools. Refer to the recommended reading textbooks for more detail.

The system gives you the coordinates of the contact point between the cam and follower when the cam has rotated this number of degrees. The point is specified with the cam resting at 0 degrees.

The relationship between cam angle and contact point coordinate is as follows. Each point on the cam will be in contact with the follower at some time in the cam's motion. The cam angle gives the number of degrees the cam has to turn for the point specified in this row of the Data Table to be the contact point.

The point shown will be in contact with the follower when the cam has rotated by the angle specified in the Cam Angle column. Analytix/Cams stores the point with the cam at 0 rotation so the polygon formed by joining these points actually provides a cam profile.

For a linear cam, the Cam Angle column is replaced by a Cam Displacement column. For a barrel cam, the x coordinate is the angle of the barrel cam.



The items below appear as column headings in the Data Table.

- Cam Angle - Each row of the table represents the relationship between the cam and the follower at a specific moment in the motion of the cam. The cam angle gives the number of degrees the cam has rotated at that moment.

Note: For linear cams this will be a cam displacement and the column heading will become Cam Displacement.

- **s (Displacement)** - This is the displacement of the follower away from the base displacement. (The base displacement is the location of the follower relative to the base circle.)
- **v (Velocity)** - The velocity of the follower expressed in terms of cam angle. (Example: if the cam angle is θ , $v=ds/d\theta$)
- **a (Acceleration)** - The acceleration of the follower again in terms of cam angle $a=dv/d\theta$.
- **j (Jerk)** - The jerk (derivative of acceleration) again in terms of cam angle $j=da/d\theta$.

Below is a table of units for these quantities for the different cam/follower types.

	Cam	s	v	a	j
Disposition	Angle/				
Plate Recip.	deg	length	length/deg	length/deg ²	length/deg ³
Plate OSC.	deg	deg	deg/deg	deg/deg ²	deg/deg ³
Linear Recip.	length	length	length/length	length/length ²	length/length ³
Linear OSC.	length	deg	deg/length	deg/length ²	deg/length ³
Barrel Recip.	deg	length	length/deg	length/deg ²	length/deg ³
Barrel OSC.	deg	deg	deg/deg	deg/deg ²	deg/deg ³

- x (Cam Profile Coordinate) - Contact point x coordinate. This is the point of contact between the cam and the follower at the given cam angle. For a barrel cam, the x coordinate column gives

the angle of the contact point on the cam surface.

- y (Cam Profile Coordinate) - Contact point y coordinate. This is the point of contact between the cam and the follower at the given cam angle.
 - r (Cam Profile Polar Coordinate) - Contact point r coordinate. This is the distance (for a given cam angle) from the point of contact between the cam and follower and the center of the cam base circle.
 - θ (Cam Profile Polar Coordinate) - Contact point θ coordinate. This is the orientation (for a given cam angle) of the line from point of contact between the cam and follower and the center of the base circle.
- ⊠ Note: The contact points define the profile of the cam.
- r.o.c. (Radius of Curvature) - r.o.c. gives the radius of curvature of the cam at the contact point.
 - Pressure Angle - Gives the angle between the direction of motion of the follower and the direction of the axis in transmission. For flat face followers, the pressure angle is 0.

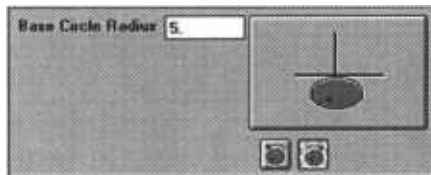
Cam/Follower Configuration Area

The Cam/Follower Configuration Area: Allows you to select from a drop-down menu the combination of cam and follower you are designing.



An illustration representing the cam and follower combination appears below as you select from the menu. Any special considerations for different cam and follower types are identified below.

Plate - Reciprocating Flat Face



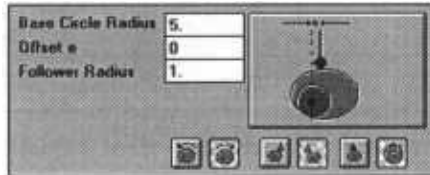
- **Base Circle Radius** - This is the radius of cam's base circle. (The follower has 0 displacement when it is lying on the base circle.)

- **Buttons:**

Clockwise/Counter Clockwise - Specifies direction of the cam rotation, either clockwise or counter-clockwise

- **Velocity Units**- length/degrees

Plate- Reciprocating Roller



- **Base Circle Radius** - This is the radius of cam's base circle. (The follower has 0 displacement when it is lying on the base circle.)
- **Offset** - The distance the follower is offset from the line going through the axis of the cam.
- **Follower Radius** - The radius of the follower roller.
- **Buttons:**

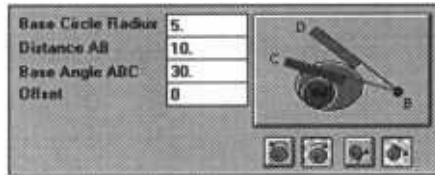
Clockwise/Counter Clockwise - Specifies direction of the cam rotation.

Follower Orientation - Specifies whether the follower is oriented above or below the cam.

Internal/External Cam - Specifies whether you want an external or internal cam (or the external or internal surface of a slot cam).

- **Velocity Units** - length/degrees

Plate - Oscillating Flat Face



- Base Circle Radius - This is the radius of cam's base circle. (The follower has 0 displacement when it is lying on the base circle.)
- Distance AB - The distance from the cam axis to the pivot point of the follower.
- Base Angle ABC - The angle between the follower and the line between the cam axis and the follower pivot when the follower lies on the base circle.
- Offset - The distance of the contact face of the follower from the pivot arm. Positive offset is in a direction toward the cam. Negative offset is in a direction away from the cam.
- Buttons:
 - Clockwise/Counter Clockwise - Specifies direction of the cam rotation.
 - Follower Orientation - Specifies whether the follower is oriented above or below the cam.
- Velocity Units - degrees/degrees

- ⌘ Note: Changing the base radius of the cam automatically changes the base angle.

Plate-Oscillating Roller



- Base Circle Radius - This is the radius of cam's base circle. (The follower has 0 displacement when it is lying on the base circle.)
- Distance AB - The distance from the cam axis to the pivot point of the follower.
- Base Angle ABC - The angle between the follower and the line between the cam axis and the follower pivot when the follower lies on the base circle.
- Arm BC - The distance from the follower pivot to the center of the roller.
- Follower Radius - The radius of the follower roller.
- Buttons:
 - Clockwise/Counter Clockwise - Specifies direction of the cam rotation.

Follower Orientation - Specifies whether the follower is oriented above or below the cam.

Internal/External Cam - Specifies whether you want an external or internal cam (or the external or internal surface of a slot cam.)

- Velocity Units - degrees/degrees
- ⌘ Note: Changing the base radius of the cam automatically changes the base angle.

Barrel - Reciprocating Follower



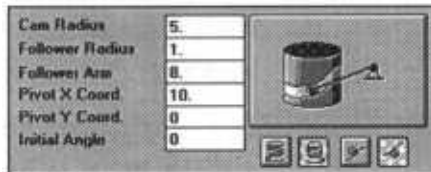
- Cam Radius - The radius of the barrel cam.
- Follower Radius - The radius of the follower roller.
- Buttons:

Barrel Rotating Left/Right - Specifies the direction of the cam. Indicates whether the active surface of the barrel cam is moving to the right or to the left when the cam is rotating.

Upper/Lower Cam Surface - Indicates whether the cam surface is on the top or bottom.

- Velocity Units - length/degrees
- ⊠ Note: The x coordinate is the angle on the barrel cam measured in degrees.

Barrel - Oscillating Follower



- Cam Radius - The radius of the barrel cam.
- Follower Radius - The radius of the follower roller.
- Follower Arm - The length of the follower arm from the pivot point to the center of the roller.
- Pivot X Coord. - The x coordinate of the pivot point. (The leading edge of the rectangle representing the cam is assumed to start at x coordinate 0.) A positive value for x positions the pivot to the right of the cam. A negative value positions the pivot to the left of the cam.
- Pivot Y Coord. - The Y coordinate of the pivot point. Y is measured from the base of the cam.
- Initial Angle - The initial angle of the follower arm (measured counter-clockwise from the

positive x axis). Angular displacements are measured with the initial angle as 0. Positive displacements represent counter-clockwise rotation of the follower.

- Buttons:

Barrel Rotating Left/Right - Specifies the direction of the cam. Indicates whether the active surface of the barrel cam is moving to the right or to the left when the cam is rotating.

Upper/Lower Cam Surface - Indicates whether the cam surface is on the top or bottom.

- Velocity Units - length/degrees

- ⌘ Note: The x coordinate is the angle on the barrel cam measured in degrees. The pivot x coordinate can be positive or negative. The initial angle is the initial angle of the follower measured from the positive x axis.

Linear - Reciprocating Follower



- Cam Width - The width of the cam.

- Follower Radius - The radius of the follower roller.

- Buttons:

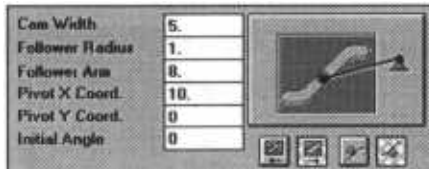
Linear Sliding Left/Right - Specifies the direction of the cam, either left or right.

Upper/Lower Cam Surface - Indicates whether the cam surface is on the top or bottom.

- Velocity Units - length/length

⊗ **Note:** Instead of cam angle, you see cam displacement.

Linear-Oscillating Follower



- **Cam Width** - The width of the cam.
- Follower Radius - The radius of the follower roller.
- **Follower Arm** - The length of the follower arm from the pivot point to the center of the roller.
- **Pivot X Coord.** - The x coordinate of the pivot point. (The leading edge of the rectangle representing the cam is assumed to start at x

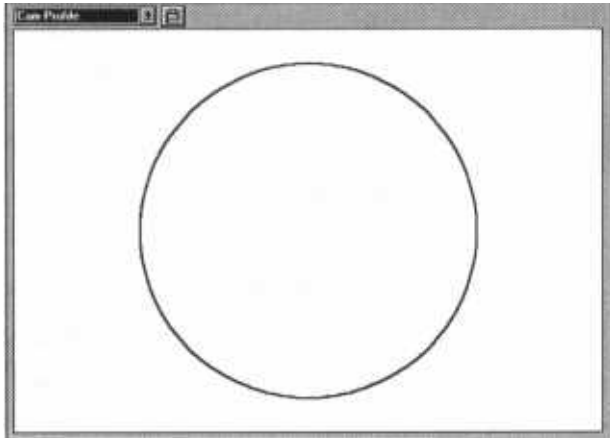
coordinate 0.) A positive value for x positions the pivot to the right of the cam. A negative value positions the pivot to the left of the cam.

- **Pivot Y Coord.** - The Y coordinate of the pivot point. Y is measured from the base of the cam.
- **Initial Angle** - The initial angle of the follower arm (measured counter-clockwise from the positive x axis). Angular displacements are measured with the initial angle as 0. Positive displacements represent counter-clockwise rotation of the follower.
- **Buttons:**
 - Linear Sliding Left/Right - Specifies the direction of the cam, either left or right.
 - Upper/Lower Cam Surface - Indicates whether the cam surface is on the top or bottom.
- **Velocity Units**- degrees/length

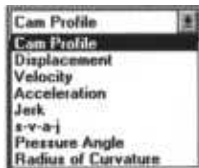
⌘ Note: Instead of cam angle, you see cam displacement. The pivot x coordinate can be positive or negative. The initial angle is the initial angle of the follower measured from the positive x axis.

Analysis Area

At any time while defining the values and parameters for the cam and follower, you can examine various graphs in the Analysis area. (This appears in the lower right portion of the main window.)



The drop down menu in the Analysis area provides views of the following properties:



- ⌘ Note: In the case of an oscillating follower type, displacement is angular.

You can also copy to the Windows Clipboard the illustration that appears in the Analysis area by clicking the Clipboard button.



This is useful for pasting data into other applications for creating project documentation, proposals, presentations and reports.

Two methods are provided for viewing displacement, velocity, acceleration and jerk, pressure angle and radius of curvature: in tabular format in the Data Table or in graphical format in the Analysis area. The numeric values for the illustration appear in the corresponding columns of the table.

Chapter 6 - Analytix/Cams Menu Reference

You see three menus in the Analytix/Cams menu bar:

File

New - Displays a new Analytix/Cams window where you can create a new design.

Open - Displays an Open dialog box where you can select a design to open. Formats you can open include Analytix/Cams files (*.cam), or comma- or tab-delimited ASCII. If you open an ASCII file with x,y or r,6 pairs separated by carriage returns, the data will be automatically inserted into the data table.

Save - Saves the current document using a name you've previously defined.

Save As - Opens the Save As dialog box, which allows you to name the document and determine the format in which to save it. Formats include DXF, CAM and tab-delimited ASCII.

Exit - Quits Analytix/Cams. If you have made modifications to a previously saved document or have not yet saved the document, you are given that option.

Edit

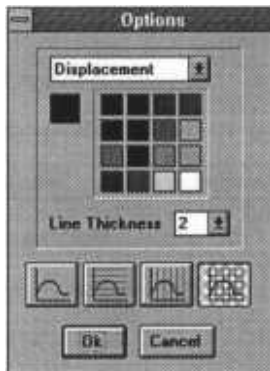
Undo - Reverses the last action to its previous state.

Redo - Works in conjunction with Undo to reverse the Undo command.

Copy - Leaves the selected text in the document and places a copy on the Clipboard for later pasting.

Paste - Places the items on the Clipboard at the insertion point in the document.

Options - Allows you to change the display options of the Analysis area.



The drop down menu provides the following options: Displacement, Velocity, Acceleration, Jerk, Axes and Background.

Colors - 16 colors are supported in the color palette. Select Displacement, Velocity, Acceleration, and Jerk and select a color option for that selection. When you select Background or Axes in the drop-down menu and choose a color in this palette, the same color applies to all views in the Analysis area.

Line Thickness - Select from 1 to 8 point line thickness.

Buttons - Click the appropriate button for the desired grid type. Options include no grid, horizontal or vertical grid or full grid.

Help

Use the items in the Help menu as an electronic reference to Analytix/Cams.