Units and Conversions

Open the View Properties Dialog for this section. Be sure to click the thumbtack icon in that form to keep it visible.

1. Enter the rule area = length * width .

2. Switch to the Variable Sheet and enter input values of 3 for length and 4 for width. Solve and TK tells us that area is 12. The units are implied by the equation.

3. Let's tell TK to do the calculation in inches. Move to the unit column and enter in for both length and width and in^2 for area. See the properties for the variable area. Both the display and calculation units are listed as in^2.
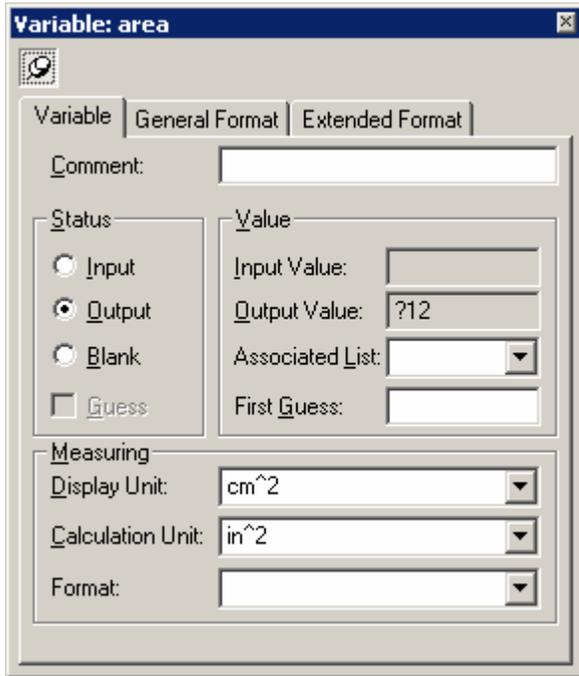

4. Open the Unit Sheet and define a unit conversion. In the From column, enter in. In the To column, enter cm. In the Multiply By column, enter 2.54.

From	To	Multiply By	Add Offset	Comment
in	cm	2.54		

5. Go to the Variable Sheet and enter cm as the unit for length. TK automatically changes the value in the input field.

The calculation unit is still inches (in) but the display is now centimeters (cm).

6. Change the display unit for area to cm^2. TK places a ? symbol next to the value. This indicates that TK does not know the conversion from in^2 to cm^2.

7. Go to the Unit Sheet and enter a second conversion from in^2 to cm^2. Enter 2.54^2 in the Multiply By column. Go to the Variable Sheet to see that TK has made the conversion.

8. Go back to the Unit Sheet and define some more conversions:

> cm to mm (enter 10)
> cm^2 to mm^2 (enter 100)
> ft to in (enter 12)
> ft^2 to in^2 (enter 144)
> ft to cm (TK automatically calculates this factor!)

9. Use the File Menu, select Save Window and save the Unit Sheet to a file called areaunit. Later, we can merge this information into another model instead of retyping it.

10. Switch back to the Variable Sheet and associate lists with each of the variables. (Remember how to do this?) Go to the List Sheet. The associated lists have the same display and calculation units as the variables on the Variable Sheet.

11. Go back to the Variable Sheet and change the display unit for area to mm^2. TK does the conversion. Now return to the List Sheet and see that the list is still in the original units. The units are linked only during creation of the list. Any changes to either the variables' or the list's units are done independently.

12. Use the Applications Menu to access the TK Library and select the Utilities Section. Then select the Units section and merge one of the Unit Sheets into the current model.
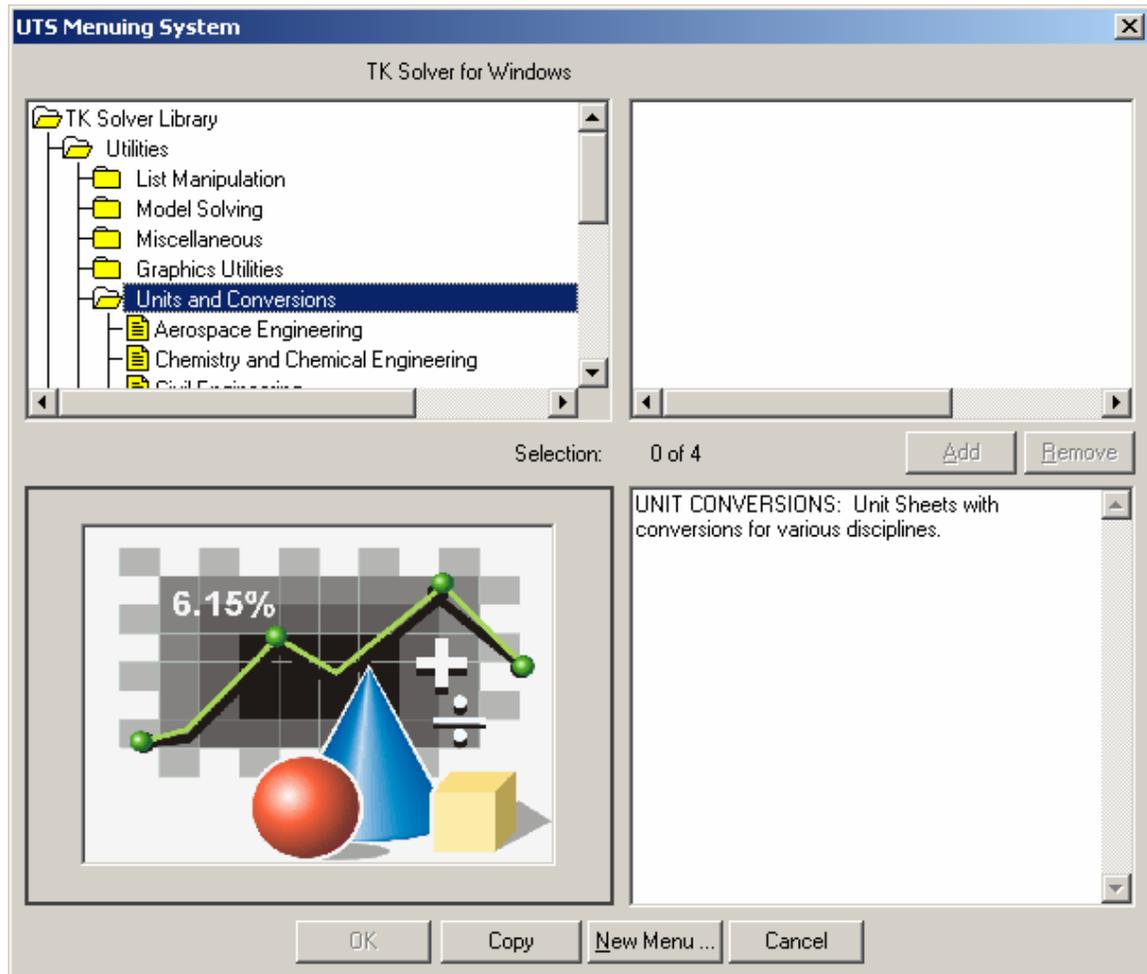
Summary:

• Your initial entry in the Unit field assigns both the calculation and display units to the variable. Subsequent entries change only the display unit.
• Units are not like variables. They are simply text strings. TK does not recognize that in^2 means "inches squared."
• Conversion factors work in both directions. If in to cm is defined, then TK can also convert cm to in.
• Conversion factors can be chained. Given in to cm and cm to mm, TK knows in to mm.
• There are no built-in unit conversion factors. You must define your own or merge in a Unit Sheet which was previously created. See the TK Library or Units Import Wizard.
• Lists can also have calculation and display units.
• Associated lists initially take on the display and calculation units of the variables. However, subsequent changes ARE NOT linked.
• Open the View Properties Dialog to get a better view of the units for all variables.

If you make an error when initially entering a unit, DO NOT type over the mistake. TK will interpret the initial entry as the calculation unit and then attempt to convert to the second entry as the display unit. Blank the field using Edit Cut or use the spacebar.

TK UNIT WIZARDS

The Object Units Summary Wizard provides a listing of all possible units which are available for a particular variable. The wizard displays the calculation and display units for the variable along with a listing of units. You just pick the one you want and TK updates the Variable Sheet. Rumor has it that TK6 will make this wizard obsolete…

The Global Units Summary Wizard allows for global switching of units throughout the Variable Sheet. You can define unit groupings (such as US and Metric) and swap between them.

The Units Import Wizard presents categories of units to load into TK's Units Sheet.
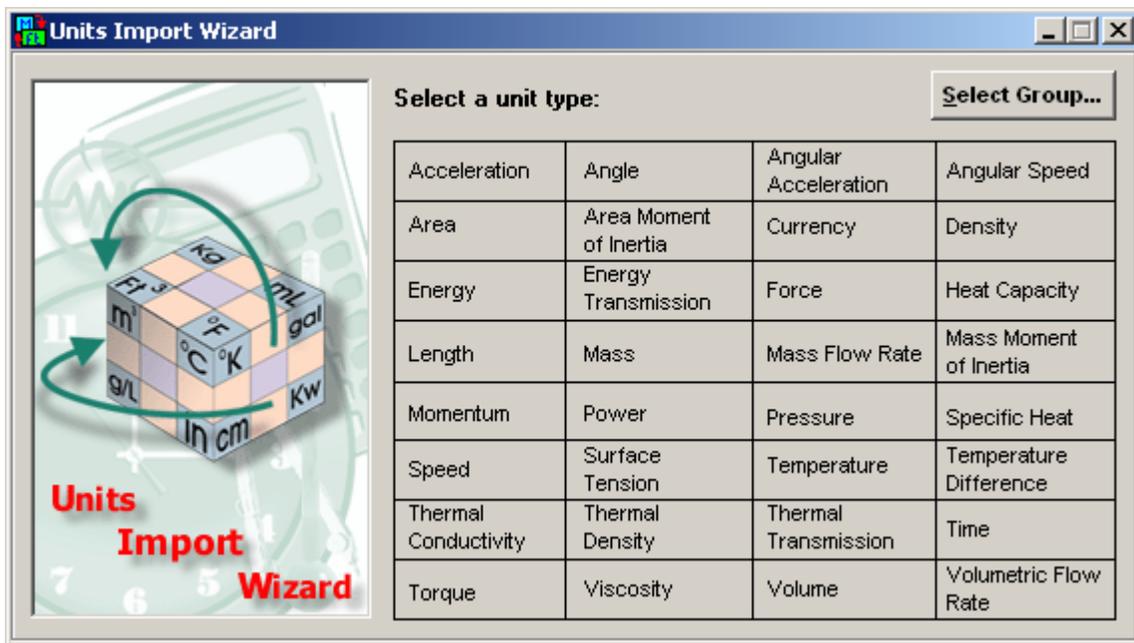
Review Exercise

Enter the following equations on the Rule Sheet.

$$\text{loan} = \text{price} - \text{down}$$
$$X = \text{loan}*(r/(1-(1+r)^\wedge\text{-}n))$$
$$pk = X*((1+r)^\wedge\text{-}(n\text{-}k)\text{-}(1+r)^\wedge\text{-}(n\text{-}k+1))/r$$
$$ik = X - pk$$
$$T = X*n$$
$$Ti = T - \text{loan}$$

You may recognize these formulas as those used for evaluating consumer loans.

Here the variable sheet after reorganizing and the addition of comments.

```
=================== VARIABLE SHEET ============================
St Input---- Name--- Output--- Unit----- Comment-----------------
             price                       Price
             down                        Down payment
             loan                        Loan amount
             r                           Interest rate
             X                           Monthly payment
             n                           Number of monthly payment
             T                           Total of all payments
             Ti                          Total interest paid
             k                           Payment to be studied
             pk                          Principal paid in kth payment
             ik                          Interest paid in kth payment
```

In this example, units play an important role. As implied by the equations, the variable r is being calculated as the *monthly interest rate in decimal form.* Unfortunately, we don't usually think in these terms. Instead, we talk about annual rates in percents.

Enter **monthly** as the unit for the variable r. Go to the Unit Sheet and add the following conversion.

monthly to %/yr (enter 1200 for the conversion factor)

Go back to the Variable Sheet and change the display unit for r to %/yr. Let's try it out on a few sample problems.

Given:
      price = 24000
      down = 6000
      r = 10 (%/yr)
      n = 48   (this is the term of the loan, in months)
      k = 1 (this is the current month number)

1. What is the monthly payment and total interest on this loan?

2. The buyer can only afford payments of $425 per month. What interest rate would make this possible? What change does this make in the total cost of the loan?

3. The buyer negotiates the deal at 9% interest. What monthly payment did they settle for? List solve and set up a table showing the principal and interest paid in each of the 48 payments. Show these curves on both a line chart and a bar chart. Try the stacked bar option.

Save the file with the name Loan.

Formats

Numeric Formats are TK objects just like lists and tables. Formats can be assigned to variables or lists or columns in tables. A format can be assigned as the Global Format in the Options menu. This format will then be assigned to all variables, lists and tables unless another format is specifically designated for those objects.

For practice, create a format and assign it to a variable.

Comments

Comments are also TK objects. Comments have several unique features.

They can be linked by using an asterisk within a comment. For example, if a comment includes the text *uts, you can navigate directly from the current comment to the "uts" comment using a right-click.
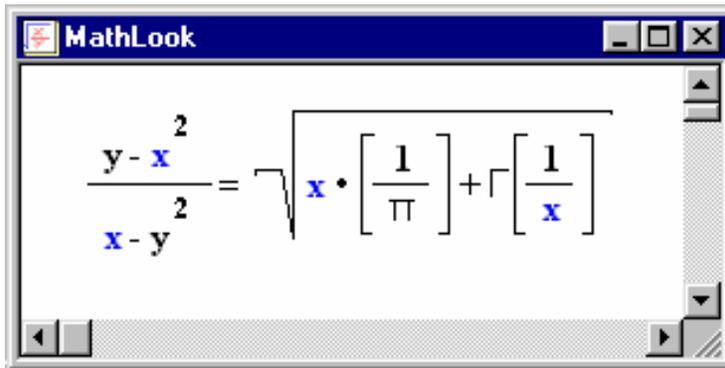
Comments on the List Sheet have a dual role in that they are used as the plot legend text for those lists.

We suggest that before you save a TK model, create a comment displaying the author, date, and some description of what the model does. The next time the model is opened, the comment will be a nice summary.

MathLook

The MathLook View at the bottom of the TK screen automatically formats whichever rule or function statement is highlighted in the current sheet. You can right-click in the MathLook View to copy the equation to paste into another program.

TK Solver also includes a MathLook Sheet that formats multiple rules and can also include other graphics images. Highlight rules on the rule sheet or functions and copy them. Then paste them into MathLook and you will see them formatted. MathLook is not intended for use as a report writer but rather a utility for converting formulas and collecting graphics prior to copying and pasting into reports.

Report Writing

There are two approaches you can take in producing reports based on TK models.

1. Copy and paste into Word or Excel.
        or
2. Use the TK Report Writer (File – Create Report).

Option 1 has several advantages. You have complete control over what goes into the report. If you Paste Special with the Paste Link option, the TK objects in the document will automatically update when you make changes to the model. You can insert text wherever you like. Option 1 was used to create these training documents.

Option 2 can be more efficient, especially if you intend to include many different TK objects in the report. The resulting report can be converted to an .RTF file that can be subsequently edited in Word but many of the graphical objects don't make it cleanly through the conversion process so you may need to copy and paste those manually.

Sample Exercise

Create a TK Solver model using the following formulas.

> volume = 1/3 * pi() * radius^2 * height
> radius^2 + height^2 = slant^2
> surface = pi() * radius * slant
> tand(theta/2) = radius/height

Assign units to each of the variables using "in" as the base unit of length and "deg" for the angle. Merge in a unit sheet from the TK Library.

Input 20 for the volume and 3 for the radius and solve.

Use the List Solve Wizard to generate a table and plot of surface vs. radius as the radius ranges from 1 to 5 in steps of 0.2. Assign formats to the columns of the table as well as the variables on the variable sheet.

Use the Optimizer to determine the radius resulting in the minimum surface value.

Copy the equations into MathLook.

Add a comment to the model, organize the sheets and save the file as CONE.

Create a report using File-Create Report.

Copy the variable sheet and paste special, linking as a TKW Document Object in Word. Change the inputs in TK and solve. Check to see that the variable sheet updated in Word. Try the same process with the plot.
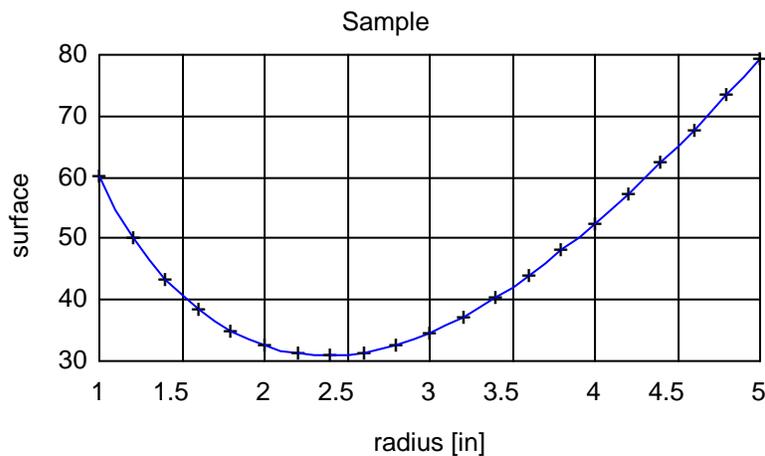
Linking TK Solver Models with Excel

TK Solver models can be linked with Excel spreadsheets for several purposes. You can use Excel to build a custom interface/report for the TK model. You can use Excel as a dashboard for linking multiple TK models together, where the results of one model might be used as inputs in others. You can use TK Packager with a linked spreadsheet to create and distribute applications to end users with access to Excel (but not necessarily TK).

The prerequisites for linking are as follows:

The TK model file must be saved.
The model must be configured with a particular set of inputs and outputs. You cannot link a model that has no inputs or outputs.
The model must solve without the use of a guess on the variable sheet. Default first guesses on variable subsheets are ok. Guesses based on other input variables can also be programmed in TK and triggered by default first guesses on variable subsheets.
If list solving is required, the variable sheet must include the proper configuration.
The TK model must not include any of the following functions: PROMPT, QUERY, MENU. All such data gathering should be done in Excel.
The TK model may include the error trapping functions (ERRMSG, DEBUG, PAUSEMSG) but they will be ignored in Excel. Any reporting of messages should be programmed in the Excel interface.

The TK Solver-Excel Toolkit installs as an Excel Add-in under the Tools menu. A set of optional toolbar icons is available as well. For this exercise, we start with a new spreadsheet. With A1 as the active cell we click the Insert TK Model icon from the toolbar. The Toolkit prompts for the name of the file. Use the CONE model.
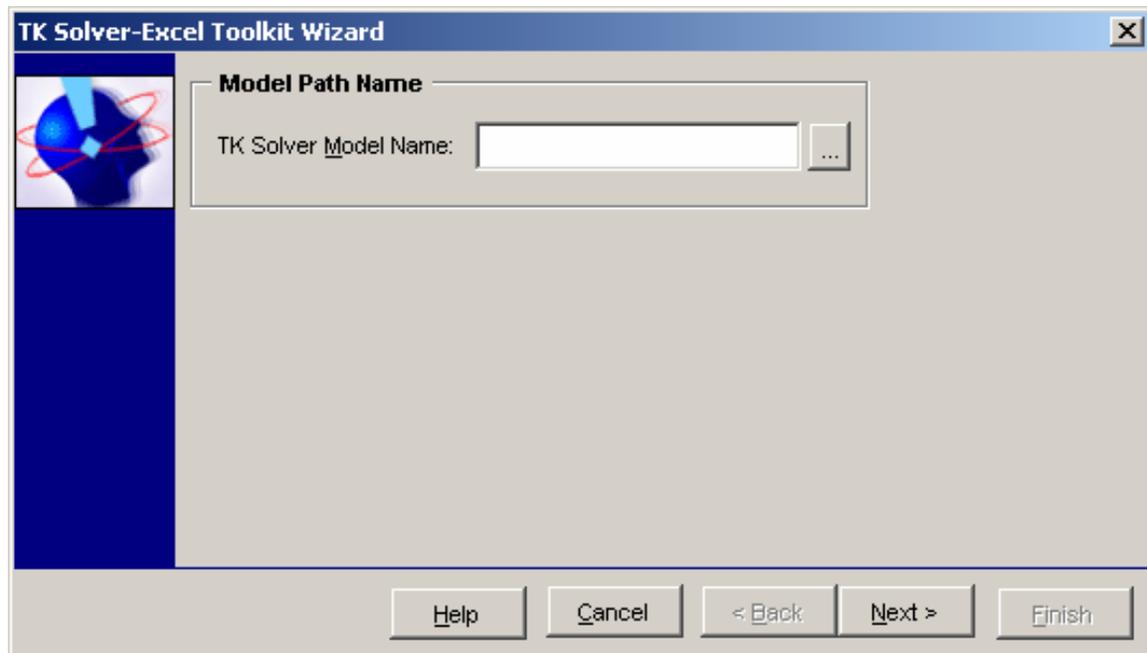
The Wizard automatically displays those variables with inputs. If you choose not to link any of these input variables, they will act like constants in the model. You will not be able to change them from Excel. In this exercise, we will use all the inputs and outputs.
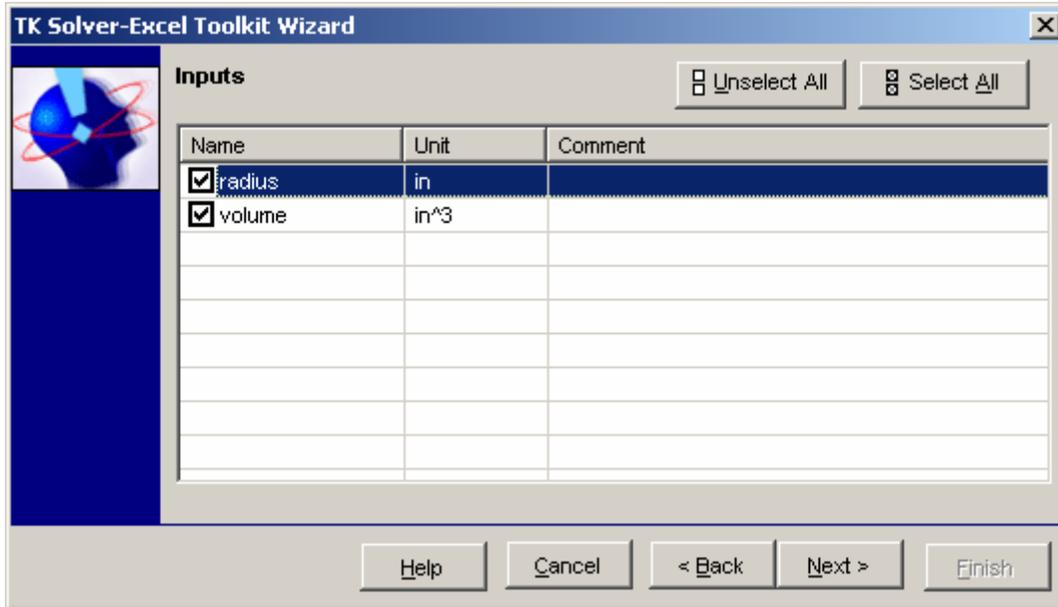
Click Next to accept the inputs and then the outputs.
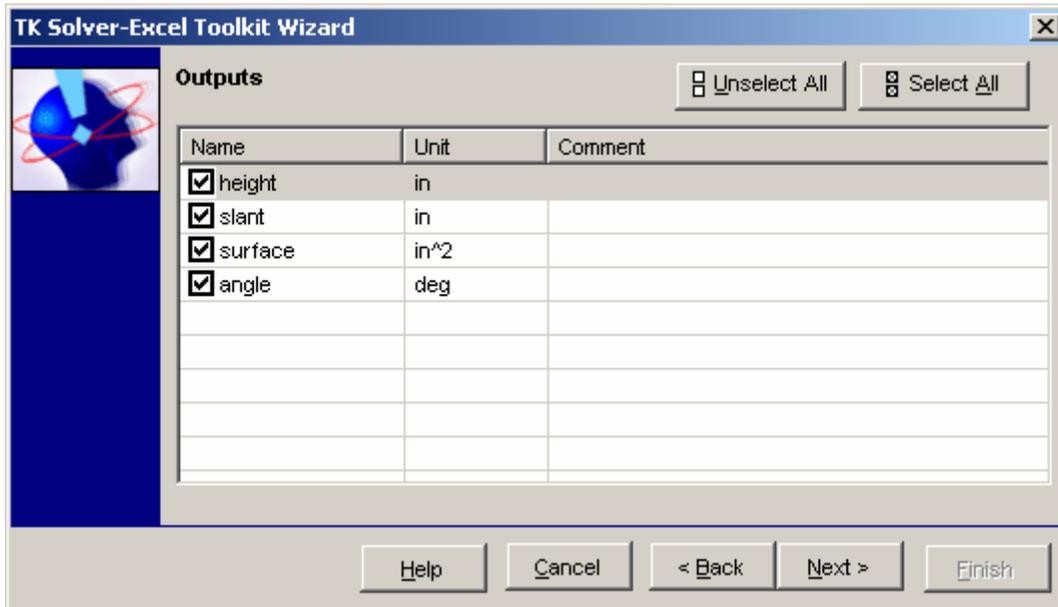
Because this model is set up for list solving, the link will solve for the variables on the variable sheet and also list solve.

The next two forms allow you to link plots and tables. Since our model has a plot, we will link it. It is important to note that the tables and plots are not editable within Excel. If you would like to edit the data you must follow a separate process for linking the underlying lists. For now, click Next to accept the default links until you come to the form with options involving units, comments, and formats.

In this exercise, we will include the units from the TK model since our model has no comments.
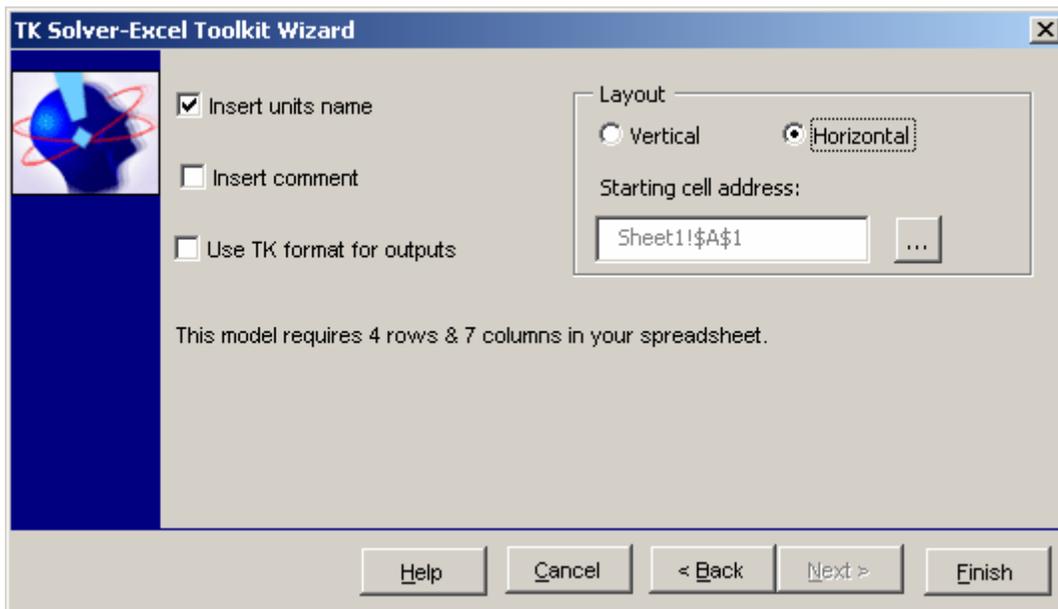
You are strongly advised to avoid the use of the TK formats when linking to Excel. By accepting the formatted values, you are in effect losing the accuracy of the actual calculations. This will have a serious impact on all subsequent calculations, including optimizations performed by the Excel Solver. It is best to format the values in Excel and the full precision of the TK calculations will be retained. For this reason, the Link Wizard defaults to no for the use of TK formatting.

When you click the Finish button, the variables and plot appear. Here are the variables.

Input	Value	Unit
radius	3	in
volume	20	in^3

Output	Value	Unit
height	2.122066	in
slant	3.674665	in
surface	34.6329	in^2
angle	109.4522	deg

These variables are now directly linked with the TK Solver model. Try changing the radius value from 3 to 4 and watch the outputs update.

Input	Value	Unit
radius	4	in
volume	20	in^3

Output	Value	Unit
height	1.193662	in
slant	4.174306	in
surface	52.45587	in^2
angle	146.7682	deg

The Value column of the output variables contains formulas that link to TK. Here is the formula for the height output...
=TKSolverGetValue("height",TKHidden!$A$11:$A$12) If you type over these formulas the link is destroyed.

The Unit column provides a listing of available units for each variable, inputs and outputs. These are the units from the TK Unit Sheet that are chained to the calculation unit for each variable.

Input	Value	Unit
radius	101.6	mm
volume	20	in^3

Output	Value	Unit
height	1.193662	in
slant	4.174306	in
surface	52.45587	in^2
angle	146.7682	deg

You can reference these linked cells from other formulas in Excel. If you intend to do so, you should NOT include TK's unit conversion feature when you link the model. Your Excel formulas will not update in the proper units when the TK variable units are changed.

Here's a simple example. Suppose you add a formula in Excel for calculating the mass of the cone. Your formula would be a function of the volume. Assuming you have used MathLook for Excel to you're your cells, your formula might appear something like =volume*density .

Input	Value	Unit
radius	4	in
volume	20	in^3
density	70	lb/in^3

Output	Value	Unit
height	1.193662	in
slant	4.174306	in
surface	52.45587	in^2
angle	146.7682	deg
mass	1400	

If you ask TK to switch the volume unit from in^3 to ft^3, the value will decrease by a factor of 12^3. Then the mass value will also decrease by the same factor which would be confusing. The TK cells all maintain unit integrity but the new Excel formulas you may add do not. If you linked the units and then change your mind later, you can lock them up again in Excel using the Excel Toolkit Locking Option.

Click the List Link icon to link the radius and surface lists from the CONE model. When the form appears, note the two tabs for inputs and outputs. Double-click in the range field for the radius list and Excel will prompt for the cell location where the radius list will begin.

Select the Range

[_____] [Ok] [Cancel]

You can click directly in the spreadsheet and Excel will fill the form for you. Repeat the process for the output list, surface. Then click the OK button at the bottom of the list link form and the lists will appear.

Change the value of the volume in the spreadsheet and watch the surface list update. Save the spreadsheet, then close it and return to TK Solver and File New to reset TK.

Review Exercise

This sample involves water flowing though a tube. The resulting math model will compute the pressure drop due to friction as the water flows through the tube. We will add unit conversions, a table, a plot, and then link it to Excel.

Here are the equations to be used, starting with the fluid property functions:

Rule
density = $satldens(3,'water,'T,T)
viscosity = $viscosity(3,'water,'T,T,'D,density)
q = w/density
V = 4*q/(pi()*D^2)
NRe = V*D*density/viscosity
1/sqrt(f) = -4*log(eps/(3.7*D)+(1.255/(NRe*sqrt(f))))
deltap/L = f*density*V^2/(D*16.085)
gradient = deltap/L

Here is the resulting variable sheet, with comments and units and sample inputs. A default first guess of .001 works well for the friction factor, f. Do you understand why a guess is required to solve for f?

St	Input	Name	Output	Unit	Comment
					Friction Loss in a Straight Pipe
					Isothermal Turbulent Flow
	60	T		oF	Fluid temperature
		density	62.36	lb/ft^3	Fluid density
		viscosity	0.000753	lb/ft-s	Fluid viscosity
	0.2	D		ft	Inside pipe diameter
	0.0006	eps		ft	Pipe roughness
	20	L		ft	Pipe length
	0.1	q		ft^3/s	Volumetric rate of flow
		w	6.236	lb/s	Weight rate of flow
		V	3.183	ft/s	Linear velocity
		NRe	52702		Reynolds number
F		f	0.007127		Friction factor
		deltap	27.996	lbf/ft^2	Pressure drop due to friction
		gradient	1.4	lbf/ft^3	Pressure drop gradient

Use the Units Import Wizard to load up the Unit Sheet.

Use the List Solve Wizard to create a table and plot of D and deltap as D goes from 0.1 to 0.5. Change the plot scaling to Y-log.
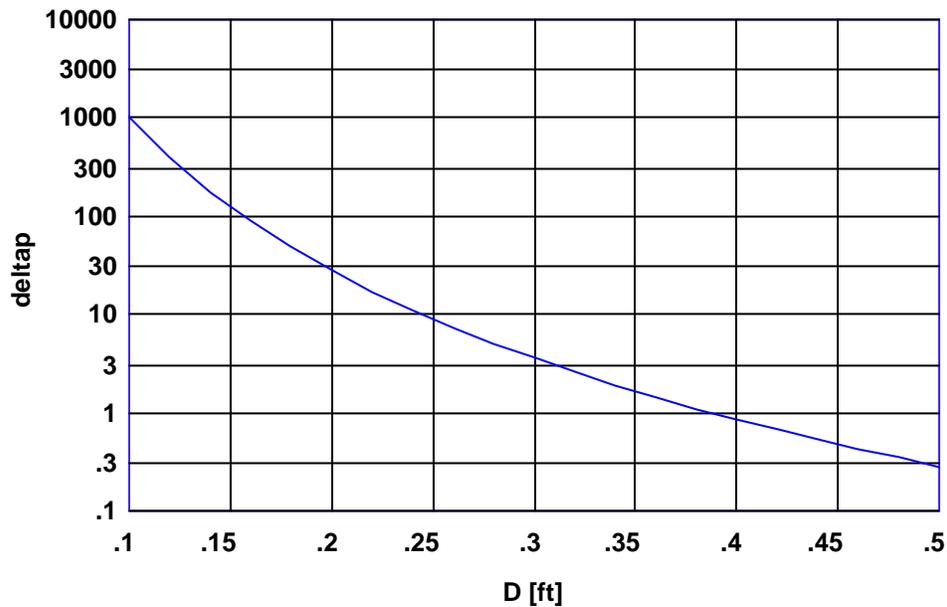
Save the model and link it with Excel.

Input	Value	Unit	Comment
T	60	oF	Fluid temperature
D	0.2	ft	Inside pipe diameter
eps	0.0006	ft	Pipe roughness
L	20	ft	Pipe length
q	0.1	ft^3/s	Volumetric rate of flow

Output	Value	Unit	Comment
density	62.36407361	lb/ft^3	Fluid density
viscosity	0.000753331	lb/ft-s	Fluid viscosity
w	6.236407361	lb/s	Weight rate of flow
V	3.183098862	ft/s	Linear velocity
NRe	52702.18965		Reynolds number
f	0.007126549		Friction factor
deltap	27.99580516	lbf/ft^2	Pressure drop
gradient	1.399790258	lbf/ft^3	Pressure drop gradient

Here is the table after linking to Excel. You can also link the lists interactively.

TK Solver-Excel Toolkit Tables

t1

Table : t1

|	D	deltap
▶	.1	1034.20821252666
2	.12	396.961586042184
3	.14	177.380731946733
4	.16	88.5868256786305
5	.18	48.1618888651715
6	.2	27.9958051613113
7	.22	17.1772418365848
8	.24	11.0193352450366
9	.26	7.33767912181006
10	.28	5.04336351522811
11	.3	3.56207054946412
12	.32	2.57598709483189
13	.34	1.9018102584124
14	.36	1.42993654677869
15	.38	1.09272039667621

Return to Spreadsheet   Solve   Copy

Lists are a special type of object. The most important trait is that their length can vary.
Because of this, their location in Excel must be handled more carefully.

The first step is to identify which lists to link as inputs.

Check the box next to the list name to link as an input. Then click in the List Range area
and click the browse icon. The wizard waits for you to click a cell in Excel and fills the
cell range for you.

This part of the process can be tricky because there are so many fields popping up on
your screen. Repeat the same process for the output list, deltap. If you need to move the
lists after linking, you can cut and paste them to a new location. For example, it's
probably best to store the lists to the right of the variables and plots. That way, you can
format the column widths without affecting the other linked objects.

You can test the list links the same way you tested the variables. Try changing the
second element in the D list from 0.12 to 0.11. You will see the corresponding deltap
value update.

When you link lists you are linking a lot more cells to TK, so you can expect the solution
process to slow a bit. Keep this in mind as you design your applications. You don't want
to link long lists unless they are absolutely required in Excel. And remember that the
Excel Solver will repeatedly update the entire list in solving for any variable, so that will
perform slower if long lists are linked.

Input:D	Output:deltap
0.1	1034.208213
0.12	396.961586
0.14	177.3807319
0.16	88.58682568
0.18	48.16188887
0.2	27.99580516
0.22	17.17724184
0.24	11.01933525
0.26	7.337679122
0.28	5.043363515
0.3	3.562070549
0.32	2.575987095
0.34	1.901810258
0.36	1.429936547
0.38	1.092720397
0.4	0.84722386
0.42	0.665501445
0.44	0.52895225
0.46	0.424941894
0.48	0.344729602
0.5	0.282166314

Now that you have these lists in Excel, you can format them as you like. You can also use the Excel graphing capability as an alternative to those in the TK Solver model. Click the Insert menu and select Chart to start the process.
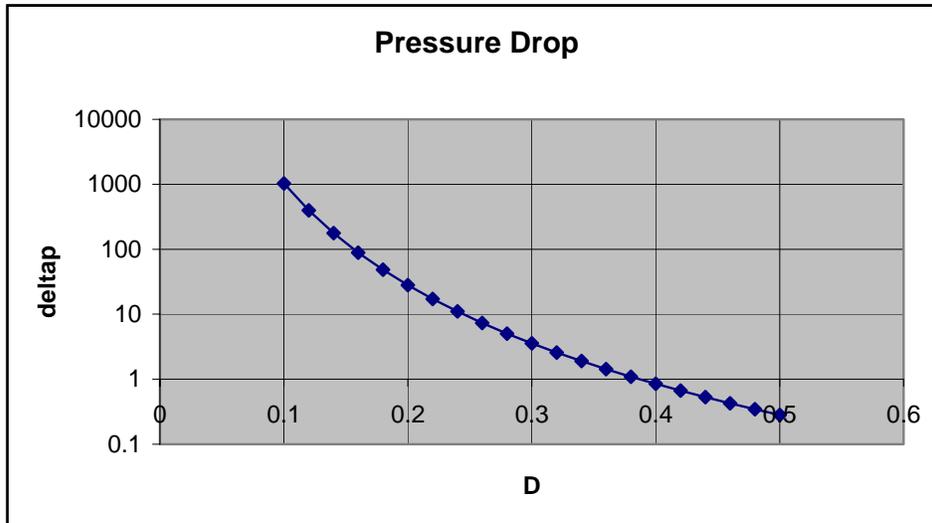
Linking Several TK Models with Excel

You may link more than one TK model to a single Excel spreadsheet. In fact, this is an excellent way to do process modeling. The results from one model can be used as the inputs for another, with everything linked and communicating within Excel.

You can also link a single model two or more times to view as multiple cases for comparison.

To link a second model, just position the cursor in a cell with room for your incoming variables and then launch the wizard by clicking on the Insert TK Model icon.

Test this with a simple TK Solver model with a single equation such as a+b = c. Link it twice in a single spreadsheet. Reference the output from the first link in a formula for one of the inputs to the second link. Here's an example.

Input	Value
a1	2
b1	4

Output	Value
c1	6

Input	Value
a2	3
b2	4

Output	Value
c2	7

The underlying TK model has the equation a+b = c with inputs for a and b and an output for c. After linking the model twice, we edited the variable names in Excel and added a formula linking the output for c1 to the input for a2, =f3/2, where f3 is the cell containing the output for c1. The shading is added for illustration only.

Obviously, if you have formulas this simple you can easily put them into a single TK Solver model. However, the process works the same regardless of the complexity of the underlying TK models.