

## Adding Calculus Functions to Excel

Excel is a good tool for organizing and summarizing data. Programs such as TK Solver are better suited for solving more sophisticated problems. Fortunately, it is easy to use these two programs together. This case study shows how TK Solver can be used to do numerical integration with the results passed to Excel.

The steps are simple. Enter the rules in TK and save the file. Link the file with Excel.

TK Solver includes a family of built-in functions for numerical differentiation and integration -- DERIV, INTEGRAL, INTEGRAL2\_FIX, INTEGRAL2\_VAR, INTEGRAL3\_FIX, INTEGRAL3\_VAR. There are also functions for solving differential equations. Note that TK built-in functions are not case-sensitive, so you can refer to them in lower or upper case. In this paper, we will use upper case to indicate functions. Here is a TK rule which finds the slope of a function at a given point.

$$\text{slope} = \text{DERIV}(\text{fun},x)$$

The variable fun must be a string value which includes the expression to be differentiated and the variable, separated by a comma. For example, fun might be equal to

$$\text{"x*(1-TANH(x)),x"}$$

The variable fun can also refer to other variables in the model but those will be treated as constants during the integration process. For example, if the variable **a** has a value of 2, then the value of fun might be

$$\text{"x*(a-TANH(x/a)),x"}$$

and it becomes more clear why the variable following the comma is required. An expression can include any number of variables, so you must specify which variable the function should actually vary in performing the differentiation or integration. It is important to note that the value of x does NOT need to be known for this expression to be processed by the DERIV function. The equation

$$\text{slope} = \text{DERIV}(\text{fun},z)$$

actually takes the value of **z** and uses it with the expression defined by fun. Think of the variable x as a local variable used in the differentiation process. Any other variables within the fun expression are assumed to be known constants.

If your functions will always be in terms of a single variable, say x, you can simplify the entry of the expression for the user by adding the following rule.

$$\text{fun} = \text{JOIN}(f,\text{"x"})$$

Now the user can simply enter the expression as the value of f, without adding the “,x” characters each time. For example, f might be assigned the expression

$$“x*(1 - \text{TANH}(x))”$$

If you assign a value to the variable x, you can have TK evaluate the expression at that value using an equation such as

$$fx = \text{EVAL}(f)$$

The eval function converts the string f into a numeric expression and then evaluates it using known values of the variables in the expression. Thus, if  $x = 0.5$ , then

$$\text{EVAL}(f) = 0.5*(1 - \text{TANH}(0.5))$$

Here is a complete TK Rule Sheet set up to solve for both a slope and an area defined by integration. It also computes the value of the expression at the given value of x.

Rule
y = EVAL(f)
fx = JOIN(f,“,x”)
area = INTEGRAL(fx,from,to)
slope = DERIV(fx,x)

Here is the Variable Sheet with inputs and outputs.

St	Input	Name	Output	Unit	Comment
	"a/x^2 + b/x"	f			expression
4		x			independent variable
2		a			parameter in the expression
1		b			parameter in the expression
1		from			lower limit of integration
4		to			upper limit of integration
		y	.375		y = f(x)
		area	2.88629438		area
		slope	-.125		slope

These variable can now be linked directly with cells in Excel.

Input	Value	Comment	Output	Value	Comment
f	a/x^2 + b/x	expression	y	0.375	y = f(x)
x	4	independent variable	area	2.8862944	area
a	2	parameter in the expression	slope	-0.125	slope
b	1	parameter in the expression			
from	1	lower limit of integration			
to	4	upper limit of integration			