CAST
COMPUTATION AND SCIENCE FOR TEACHERS

Module 2A
Turning Multivariable Models into Interactive Animated Simulations

Using tools available in Excel, we will turn a multivariable model into an interactive animated simulation. Projectile motion, Boyle's Law, nuclear decay, Newton's Law of Cooling, and population growth are just a few examples of the types of models for which a simulation can be useful to deepen a student's understanding. Knowledge of the basic aspects of Excel as covered in the earlier module is required.

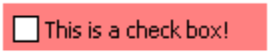
We are going to build an interactive simulation of Newton's Law of Cooling in Excel. To do this, we will collect experiment data and mathematically model it, and then build an animated multivariable simulation.

Materials needed
Computers with Excel and Internet access

Excel files: cooling_coffee.xls

Viewing a multivariable simulation
Open the Cooling Coffee Excelet which is a simulation of Newton's Law of Cooling.

You can adjust the scroll bars 

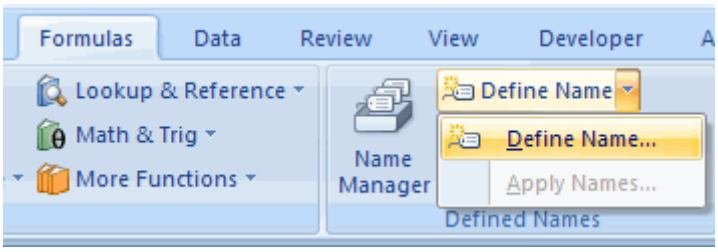
and check the check boxes. 

Take some time and explore this simulation.

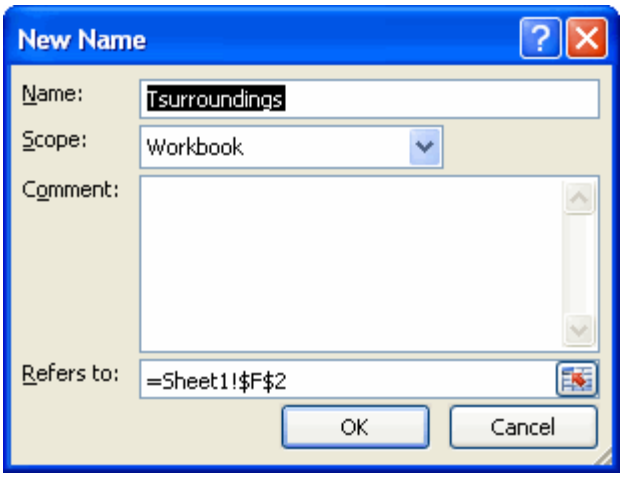
Building a Multivariable Simulation
Open the blank tab on the cooling coffee CAST spreadsheet. Set up this worksheet as illustrated in the screen shot below.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Cooling of Coffee												
2					$T_{surroundings}$ =		°C		$T_{initial\ cup}$ =		°C		k =
3													
4		time, t	T(t)	$T(t) - T_{surroundings}$									
5		0											
6		1											
7		2											
8		3											
9		4											
10		5											
11		6											
12		7											
13		8											
14		9											
15		10											
16		11											
17		12											
18		13											
19		14											
20		15											
21		16											
22		17											
23		18											
24		19											
25		20											

Now we need to place a formula to calculate in cell C5. To make the formula look more like a real formula and not spreadsheet notation, let's name the variable. Go to the Formula tab and select Define Name and then Define Name… again. This will open the New Name pop-up menu.



Click on E2 and the "Tsurroundings" will appear in the name box as seen below.



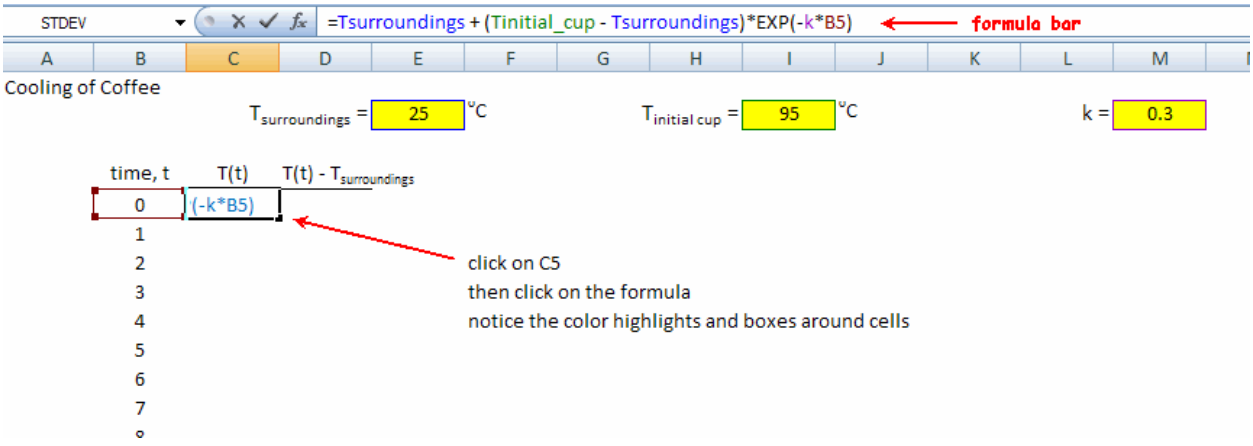
Repeat this process for the other variables. Click on I2, and then M2 to get the two variables named.

A named variable is automatically made an absolute reference. It will keep its cell reference on dragging down a formula. See absolute reference for more information.

Now if you click on C5 to compose the formula to calculate the temperature. In C5 start the formula with an equal sign and type this (you can get the variable by clicking on the appropriate cells):

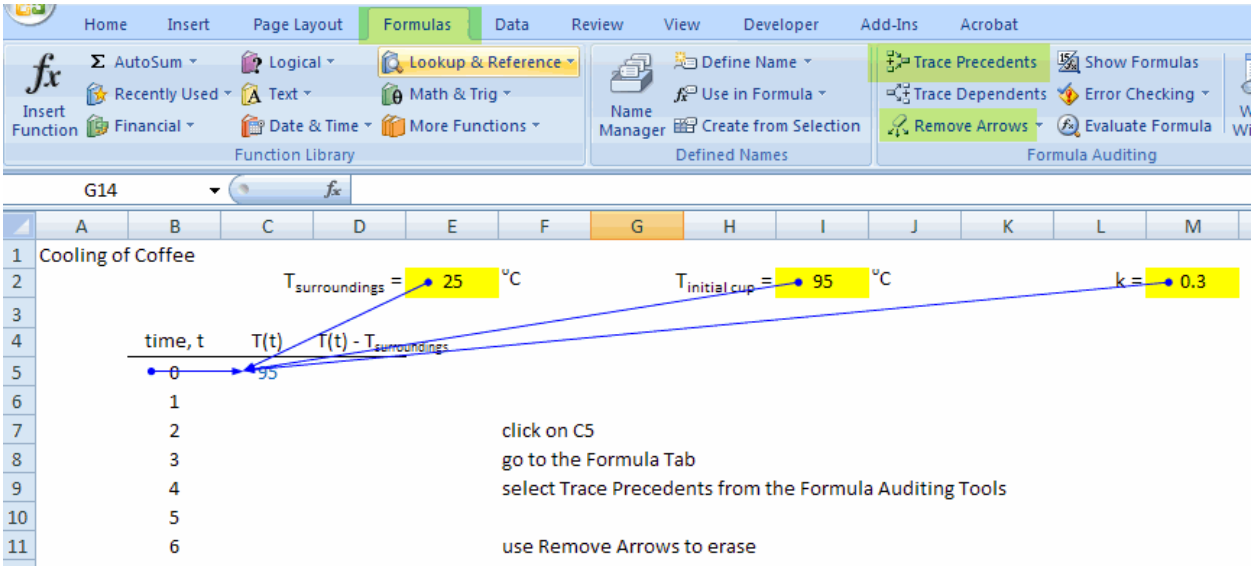
= Tsurroundings + (Tinitial_cup - Tsurroundings)*EXP(-k*B5)

After typing the formula in, click on C5 and then the formula bar (see below).

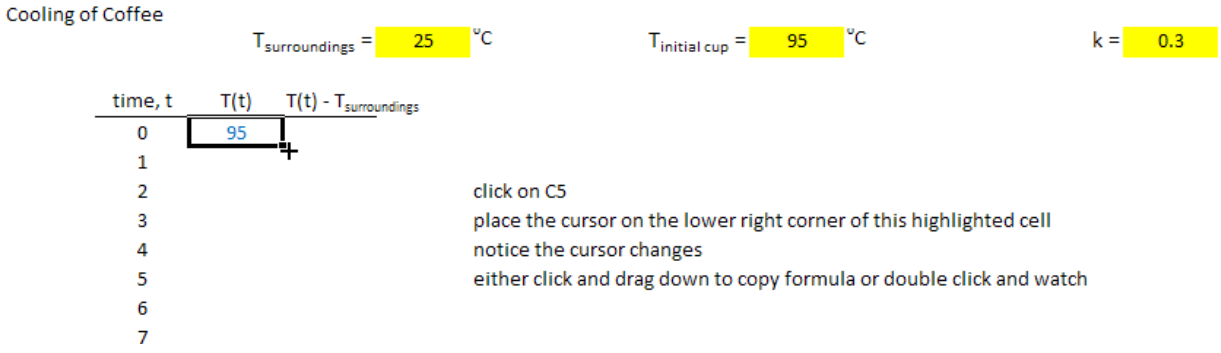


Here is another way of showing how the calculation is done using the variables.

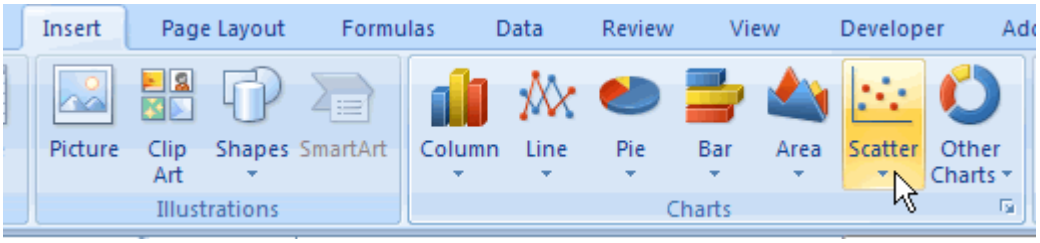
This uses the Formula Auditing tools on the Formula tab.



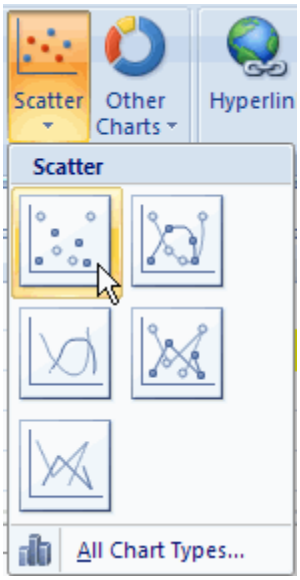
Now drag the formula down the column to complete the calculation of pressures.



Set up a graph by highlighting the data to plot, go to the Insert tab and select Scatter. This is the only plot in Excel where the x-variable is a numerical scale, all others are categories.



Now select the points only plot type from the menu as seen to the right. Your graph should appear.



If you click on the graph, it will highlight the data as shown below. Note the colors of the highlighted for the x and y variables.

Cooling of Coffee

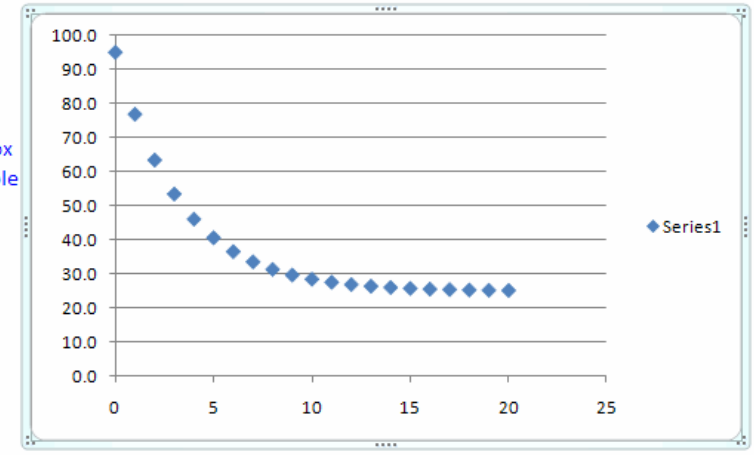
$T_{surroundings}$ = 25 °C $T_{initial\ cup}$ = 95 °C k = 0.3

time, t	T(t)	T(t) - $T_{surroundings}$
0	95.0	
1	76.9	
2	63.4	
3	53.5	
4	46.1	
5	40.6	
6	36.6	
7	33.6	
8	31.4	
9	29.7	
10	28.5	
11	27.6	
12	26.9	
13	26.4	
14	26.0	
15	25.8	
16	25.6	
17	25.4	
18	25.3	
19	25.2	
20	25.2	

purple box x-variable

blue box y-variable

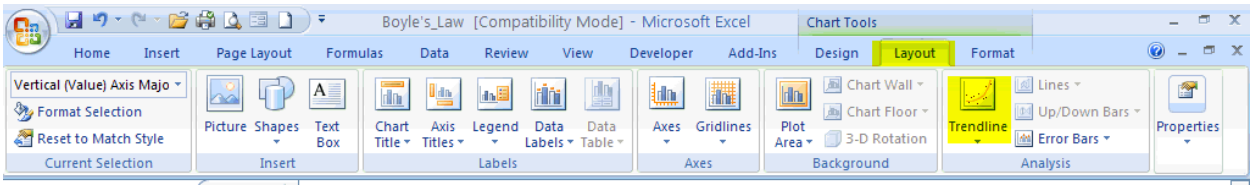
left most column is always the x-variable



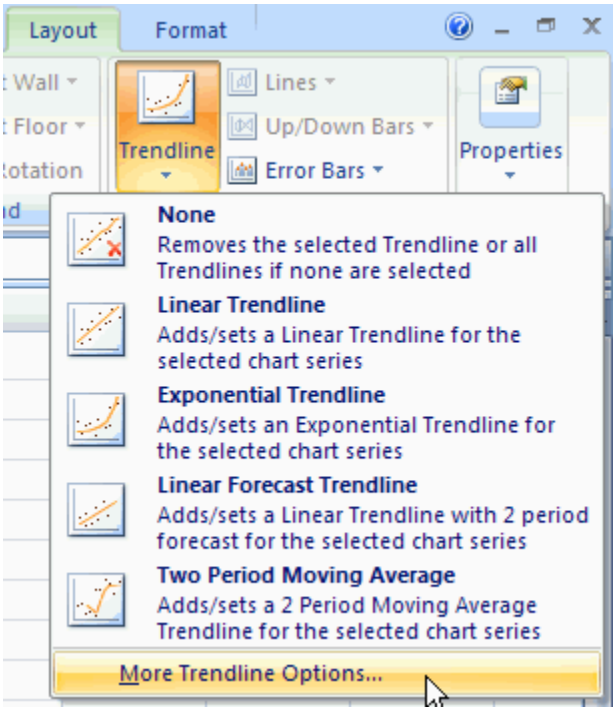
With the graph highlighted, you will see the chart tools as new three tabs appear.

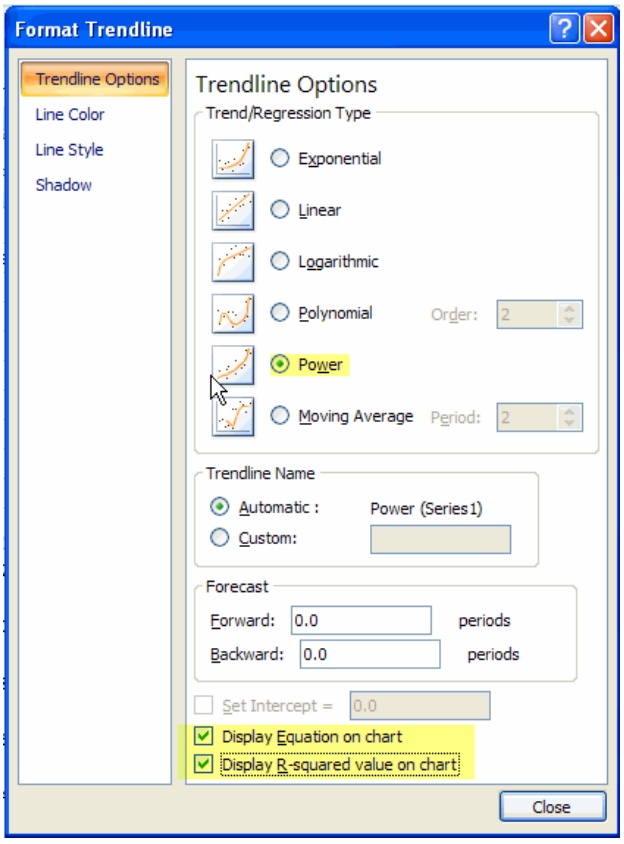
You way want to connect the data points with a smoothed curve. Click on the data points to get the pop-up menu to do this.

You can add a trendline (power regression) from the Layout tab. This tab also allows you to label axes, title, etc.



If you select trendlines (really regressions) and go to the bottom and click on More Trendline Option… the Format Trendline menu seen to the right appears.





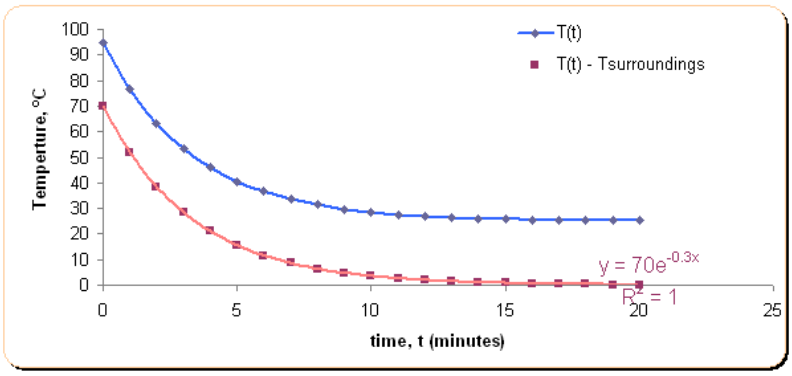
Select Power as the trendline option and select the display equation on chart and display R-square value on chart too. If you move the Format Trendline menu from on top the graph, you can select through the various trendline to explore fits.

Here is what your completed interactive spreadsheet should look like. Change the variables to see how the data and graph respond.

Cooling of Coffee

$T_{surroundings}$ = 25 °C $T_{initial\ cup}$ = 95 °C k = 0.3

time, t	T(t)	T(t) - $T_{surroundings}$
0	95	70
1	76.85728	51.85728
2	63.41681	38.41681
3	53.45988	28.45988
4	46.08359	21.08359
5	40.61911	15.61911
6	36.57092	11.57092
7	33.57195	8.57195
8	31.35026	6.350257
9	29.70439	4.704386
10	28.48509	3.485095
11	27.58182	2.581822
12	26.91266	1.912661
13	26.41693	1.416934
14	26.04969	1.04969
15	25.77763	0.77763
16	25.57608	0.576082
17	25.42677	0.426772
18	25.31616	0.316161
19	25.23422	0.234218
20	25.17351	0.173513



Consider how you might use this simulation in the classroom.

Pose some "what if" questions to use with your students.

Adding scroll bars and other features will be introduced in Module 4.