



## Turning Multivariable Models into Interactive Animated Simulations

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Using tools available in Excel, we will turn a multivariable model into an interactive animated simulation. Projectile motion, Boyle's Law, nuclear decay, 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 Excel workshops is required.

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We are going to build an interactive simulation of Boyle's Law in Excel. Boyle's Law relates how volume influences the pressure of a trapped amount of gas at constant temperature.

So first, let's examine some data collected via the following Flash animation at:  
[http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/gaslaw/boyles\\_law\\_graph.html](http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/gaslaw/boyles_law_graph.html)

Open the Excel file: BoylesLawSim\_SC08.xls

Collect 10 different volumes and pressures and record them in the spreadsheet.  
How are pressure and volume related?

From the data and graph you may see that the relationship is  $PV = \text{constant}$ . So let's see what constitutes the constant and play with some error as well.

Boyle's Law holds if temperature (T) and the amount of trapped gas (n) are constant or considering the Ideal gas law:  $PV = nRT$  where R is the gas constant (0.0821 L-atm/mole-K). So on the build your own tab, create a column of volume data for a syringe and then we will calculate the pressure as:

$$PV = k$$
$$P = \frac{k}{V} = \frac{nRT}{V}$$

Now we have two more variables to change to see how they influence the pressure and change the graph.

When you do this experiment it can be difficult to hold the syringe at constant volume especially at high pressures. So let's add some random error to the volume measurement. This will be done by the equation below, where "a" is the noise in the volume data:

$$V' = V + a*(\text{RANDBETWEEN}(-10,10)/10)$$

where "a" varies from 0 (no error) to some positive value that is multiplied by a random number between -10 to +10 using the [RANDBETWEEN function](#) in Excel.

Another error in this experiment is due to the tubing connecting the syringe to the pressure gauge or other measuring device. The tubing adds some extra volume that is not accounted for without applying a correction. So let's add this in to the equation for volume above and convert it to liters. To get:

$$V' = (V + a*(\text{RANDBETWEEN}(10,-10)/10) + V_{\text{tubing}})/1000$$

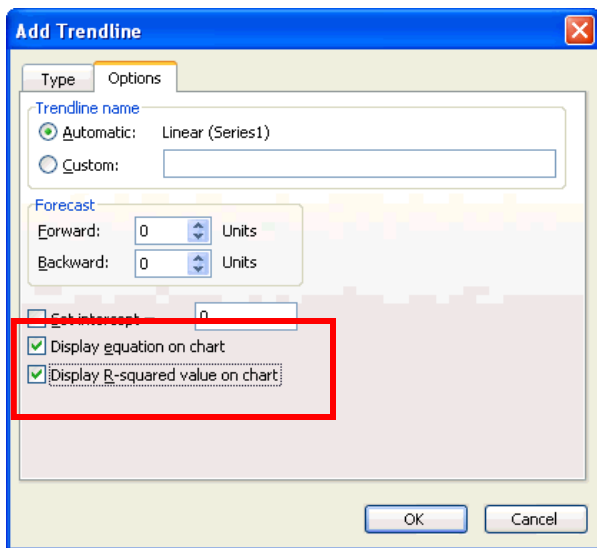
The final calculation of pressure then becomes:

$$P = \frac{nRT}{((V + a*(\text{RANDBETWEEN}(10,-10)/10) + V_{\text{tubing}})/1000)}$$

Now we have four variables to adjust in this simulation. Okay to the spreadsheet...



Now drag the formula down the column to complete the calculation of pressures. Set up a graph by highlighting the data to plot, select Insert Chart... and select an XY scatter plot. You can add a trendline (power regression) and under the option tab select as shown below.



Now if you change one of the variables on row 2, the data recalculates, the graph adjusts, and the regression recalculates as well.

How does increasing the temperature influence the curve?

How does adding random noise or error to the data influence the curve and regression?

How does the tubing error influence the results?

The Boyle's Law simulation tab gives you a version using named variables and shows some more interactive features that will be examined in the Advanced Models workshop at 3:30pm today. For further materials on mathematical modeling and developing interactive Excel spreadsheets, see the Developer's Guide to Excelets at <http://academic.pgcc.edu/~ssinex/excelets>.

For more information on the Boyle's Law simulator, see [\*The Boyle's Law Simulator: A Dynamic Interactive Visualization for Discovery Learning of Experimental Error Analysis\*](#), which appeared in **Spreadsheets in Education** 3 (1) 20-26 (<http://epublications.bond.edu.au/ejsie/vol3/iss1/2/>).