**Reference for computer data processing and graphing**

**I. Data preparation**

Each number is recorded in one cell, including repeated measurement. Use the “average” function to get the single average values of the dependent variable. Other processed variables should be added as the progress goes on. Each processed variable occupies one column with its symbol and unit at the top of the column.

**II. Plotting the first graph and formatting**

1. Highlighting two columns (numbers only) directly from the data table if they are side by side. Otherwise, select one column first, then press down the control key "CTL" and select the second column at the same time.

2. Select "INSERT" tab from the tool bar of the work sheet, choose scatter chart, and select the first graph type from Scatter Graphs. A chart with "Chart Title" appears. This graph is likely to swap the dependent and the independent variables.

3. Right click the chart area and choose "Select Data", a window appears. Click "Remove" tab to remove the current data. Then select "Add" tab to open a data dialog window.

4. In the top space type the name of the data, e.g. "Period VS Length". It becomes the title of the chart. Then click the second icon with red colour, a choice box pops up for you to select the independent variable values. Make sure it is the correct one. After selecting all the values of the independent variable, click the icon again to go back to data dialog window. Click the third icon and select all the values of the dependent variable. Click "OK" to go back to the main window. Click "OK" again to close the window. The data should be plotted correctly. Check again before you go further by putting the curser on one point and check its coordinates.

5. **To get and change names and units of axes**, click the chart to pop up a green "+" near the chart. Then tick "Axis Titles", "Trend line" from the small pop up window. Click "Axis Title" at the bottom of the chart, and change it to your independent variable with unit in brackets. Do the same for the vertical "Axis Title".

6. **To format the data points** on the chart, right click any point to pop up a selection window, select "Format Data Series" to get another window. Click the small icon near the top left corner (like an academic cap), to open the MARKERS. Click “MARKERS", then Select "MARKER OPPOTIONS", then "Built in", then "x" from drop down list of Type to get the x for data points on the chart. You can also change the size of the points by selecting a number from the box below.

7. **To format the trend line**, right click it to pop up its format window. Select "Power" and "Display Equation on Chart", an equation appears on the chart. If you change "Forward" or/and "Backward" number, you can change the length of it. Change the names of the variables to suit your need by clicking the equation first.

**III. Drawing the 2nd graph**

1. **Transform your independent variable first** by using “SQRT” function from Excel to have square root of it, or “\*”as multiplication to get the square of the independent variable. Which function to use dependents on the shape or/and equation from the first chart.

2. **Use the transformed variable and the dependent variable to draw the second graph**. Follow the procedure as above. But this time try to use "Linear" option when you format your trend line. Do not forget to change the variables of the equation before you complete the chart. The equation gives the gradient of the line of the best fit if the 2nd graph is a straight line that close to most points.

3. Add one more column to the data table to calculate the absolute uncertainty of each value of the transformed variable. Uncertainties for the dependent variable should also be available.

4. **To draw the error bars for both the dependent variable and the transformed variable,** click the chart to pop up the green “+”, then tick “error bars”, error bars appear at the data point. Click any vertical error bar, then follow the arrow towards the right to open a selection list, choose “more options…” to open “Format Error Bars” window. Tick “both” from direction, “No Cap” from “End Style”, and “Custom” from “Error Amount”. Click “Specify Value” from the bottom corner to pop up a small window to select uncertainties. Select the absolute uncertainties of the dependent variable for both “Positive Error Value” and ”Negative Error Value” from the same column of the uncertainties of the dependent variable to determine the size of vertical bars. Then click any horizontal error bar and repeat the process to select the uncertainties of the transformed variable for the horizontal error bars.

5. **Set guide points and plot error line: (1) setting the guide points:** If the vertical error bars are larger**,** one guide point should be at the high/low end of the vertical error bar at one end of the data series, and another at the opposite end of the vertical error bar. This can be done by creating two guide points from the data table by adding or subtracting the absolute uncertainty value from the original data point for the dependent variable. (2) **Draw the error line**: Follow the step of II(3) above to add two guide points (but do not use the “Remove”- that removes your main points away) to the graph by simply “add” data series from the data selection window. “CTL” key need to be pressed while selecting the coordinates of the points. Once the points are plotted, right click to select “Add Trend Line” and “Add Trend Line Equation” to show both on the 2nd chart. From two equations we can get the gradient with uncertainty and the relationship of two variables with uncertainty.

**IV Inverse relationship**

If the 1st graph shows a reverse relationship, do the transformation of 1/x first. If a straight line is obtained, use the procedure III above to deal with uncertainties and error bars as well as error line. If it gives a square root relationship or a square relationship, one more transformation is needed before getting the straight line.