COMPUTATIONAL PHYSICS WITH SPREADSHEET – I

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Introduction

Physics deals with two different approaches, namely experimental and theoretical. During, last couple of decades the computational physics has emerged as a very powerful tool to do physics.

In this series of articles, we discuss the use of spreadsheet programme to deal with simple problems in basic Physics. We use Microsoft Excel as a spreadsheet programme as it is most commonly accessible. Other spreadsheets function almost in the same manner.

In this article we discuss plotting of simple graphs as relation between physical quantities.

How to use EXCEL (Skip this section if you are already familiar with EXCEL)

When we open a new EXCEL file, it displays worksheet which has rows and columns. In each cell, we may either enter a data or a formula. When formula is entered, it calculates the result and displays it in the cell. Whether a given cell contains a formula or just data can be seen by looking at formula bar.

Each cell has a name. When we select a cell by taking the cursor on it and clicking, its name appears in the name box. The default name of the cell is its address written by column and row, e.g., A3 means column A and 3rd row or BFA36789 means column BFA and row 36789. We may change the name of the cell by typing it in its name box.

MS Excel worksheet (with office 7 version) has 16384 columns, i.e., A, B,... Z, AA, ..., AZ, BA, ..., ZZ, AAA, AAB, ..., XFD and 1048576 rows.

We can do mathematical or logical operations on data. For this we write a formula in a cell where we want the result to appear. The formula contains name of the cells containing data in place of variables. For example, if data is stored in cell A3 and B3 and we want its product in the cell G3, then in the cell G3 we write formula: '=A3*B3' (with no quotation symbols). All formulae start with '=' sign. So when the excel sees that the content of a cell starts with '=' sign, it interprets it as a formula, otherwise the contents of the cell are treated as data.

Example: if cell A3 contains 35 and cell B3 contains 2, then cell G3 will contain the answer of product of 35 and 2 in the above example.

It is possible to copy a formula from one cell and apply it to other cells. However, when a formula is copied, excel modifies the formula

that refer the data by relatively changing the cell addresses.

Example: from the above example if the formula in cell G3 is copied to G4, the formula will automatically change to '=A4*B4'. Since, the formula is shifted one row below, all the addresses are also shifted down by one row. This most of the times turns out to be a very useful feature.

Now if the formula from G3 is copied to J3 (i.e., 3 columns to right) then it automatically changes to '=D3*E3'. So we have to be careful when we copy the formula from one cell to another.

Applying formula to multiple cells

When we want to apply the same formula to multiple cells, we may use any of the following methods:

1. Drag the formula
2. Copy and paste the formula

Enter the formula in one of the cells and press Enter key. This will make Excel to evaluate the formula and store the result. Now take the cursor to the bottom right corner of the cell containing formula so that the cursor changes from white + sign to the dark + sign. Now click the mouse left button and drag the cursor to all the cells where formula is to be applied. This method is useful when the formula is to be applied to an entire row or column.

Alternately, after evaluating the formula where it was entered first, keep the cursor on that cell, and copy the cell. For copying the cell, we can right click on mouse and select copy in the appeared menu or use the short-cut key CTRL+C (i.e., press CTRL button on keyboard, and while this button is kept pressed, also press button C). This will copy the formula from the cell to internal memory clipboard of Excel. When contents of cell are copied, the cell gets a dotted blinking border. Now wherever we want to apply the formula, select those cells and paste it by pressing CTRL+V on the keyboard or right click the mouse on the selected cell and click on paste. Even after pasting the contents, the original cell contents are still in the memory. To remove that, press Esc key. This will remove the contents from memory clipboard and the blinking border will also disappear.

Locking the cells

Many times we may want to use the same constant in formulae for the entire data set. For example, if we want to calculate the function. We may put x values in column A and the calculated function in column B. So, x values may be from cells A5 to A15. Now the constant A we may write in cells say A2. To evaluate the function for the first data point, we may write formula '=A2*EXP(-A5)' in cell B5. However, when we copy the formula from B5 to B6, it will not only change the variable x from A5 to A6, it will also change the cell reference A2 to A3. This will cause an error as the constant is written only in cell A2 and not in A3. So we need to lock the cell A2 in the formula. This is done by using $ sign before the row number in A2, i.e., instead of referring it as A2 we shall write this as A$2. The formula in B5 then will be '=A$2*EXP(-A5)'. This when copied to cell B6 will read as '=A$2*EXP(-A6)'.

Plotting data

For plotting data we may use a chart. For plotting the points of data, select the data cells and then click on Insert tab → Scatter button in Charts group. There are five different options of scatter plot: 1) only

points, 2) consecutive points are joined by straight lines, 3) consecutive points are joined by smooth curves, 4) and 5) points are joined like in 2nd and 3rd option respectively, but the points themselves are not displayed.

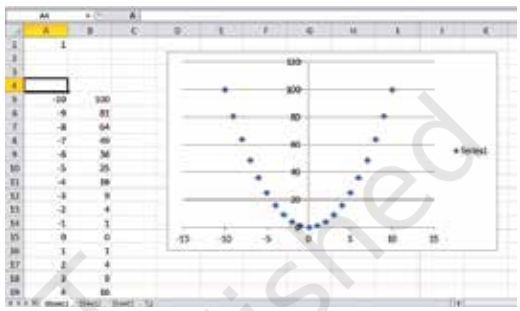
The charts are not graphs, in a sense that no best fit curve is drawn for the given data points. For best fit curves there is an option of adding trend lines, but we shall not discuss that here.

Example

Suppose we want to plot the x^2 function.

We decide to take x values from –10 to 10 in the step of 1.

1. We enter –10 in the cell A5.
2. We enter incremental step value of 1 in cell A1.
3. We write formula in A6 as '=A5+A$1' (A$1 implies the cell A1 is locked in the formula). When we press enter, it shows the value –9.
4. Now we drag this formula up to cell A25. Cell A25 will display value 10 whereas the formula bar shows that it actually contains the formula '=A24+A$1'
5. This has given us x data points from -10, -9,..., 0,..., 9, 10.
6. Now in cell B5, write the formula '=A5^2'. (^ symbol indicates the raised to operation. So here it is content of A5 cells are raised to 2.) and press Enter.
7. The cell will show the result 100.
8. Drag the formula till B25.
9. So we finally get the numbers in B5 to B25 as 100, 81, 64,....,0,..., 81, 100
10. Select the cells A5 to B25.
11. Click on Insert tab → Scatter (in charts tab) → first option of only points.
12. You will see the points in parabolic pattern.



Consider another example.

Example: Suppose we want to plot the following relation.

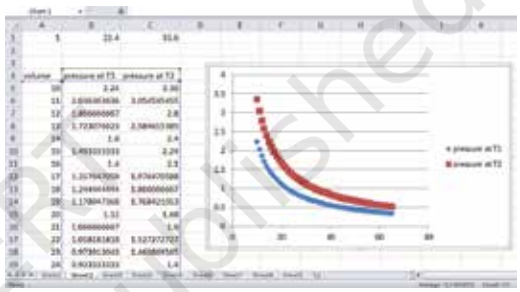
We decide to simulate real life data: let the constant be 22.4atm-litre. Now let's see how pressure varies as volume is changed from 10 litres to 65 litres. (Excel only handles the numbers, we interpret and assign the units.)

1. Put incremental volume of 1 in A1, constant 22.4 in cell B1.
2. Enter 10 in cell A5.
3. Write the formula '=A5+A$1' in cell A6 and press Enter. Drag the formula in cell A6 to A60. We get the volume values from 10 to 65 in the steps of 1.
4. Enter the formula '=B$1/A5' in cell B5 and drag it upto cell B60. These are then the values of pressures (in atm) as predicted by Boyle's law.

5. Select the cells from A5 to B60. Click on Insert tab → Scatter button (in charts tab) → select first option of Scatter with Only Markers.
6. We see the hyperbolic curve of Boyle's law.

Now we may add another set of data in the same worksheet and chart for a different constant. Say for the same gas if the temperature is increased and for this increased temperature the constant is say 33.6 atm-litre.

1. Write this new constant 33.6 in cell C1.
2. In cell C5 write the formula '=C$1/A5' and enter. Drag the formula upto cell C60.
3. Write the labels for the columns in 4th row, Volume in A4, pressure at T1 in B4 and pressure at T2 in C4.
4. So we get the new values of pressure corresponding to higher temperature.
5. Now right click on the chart's plot area.
6. Click on Select Data. A dialogue box opens.
7. Click on 'Add' under Legend entries (series).
8. A box for edit series opens.
9. Click on the icon given in Series X values. The box reduces only to show X values. Click on A5 and drag till A60. The series X value will automatically update to '=Sheet1!$A$4:$A$60'. Again click on the icon in the box. The original dialogue box will appear.
10. Now in Series Y values click on the icons. In the reduced Y values box, click on C5 and drag till C60. The series Y values will automatically update to '=Sheet1!$C$4:$C$60'. Again click on the icon in the box. The original dialogue box will appear. Now click on Ok and then again Ok on Select Data Source dialogue box.
11. The original chart has now two curves in two colours. They are represented as pressure at T1 and pressure at T2.



Just to feel comfortable, one may try following exercise and build familiarity with spreadsheet.

Exercise

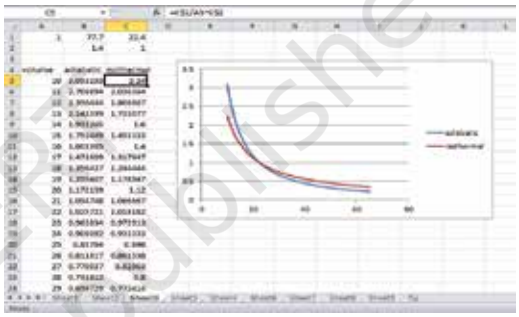
1. The displacement of an object under uniform acceleration is given by $S = ut + \frac{1}{2}at^2$. Consider a car accelerating from zero initial velocity with an acceleration of 1.00m/s2. Plot the displacement as a function of t from 0s to 60s.
2. Consider a ball thrown up with a speed of 30.0 m/s. Calculate and plot the displacement of the ball taking acceleration as –9.8m/s for time t = 0.0s to 6.0s in the incremental step of 0.1s.

Adiabatic curve pV^{γ} = Constant

Let γ be 1.4 and the constant be 22.4atm-litre. Now let's see how pressure varies as volume is changed from 10 lit to 65 lit. (Excel only handles the numbers, we interpret and assign the units.)

1. Put incremental volume of 1 in A1, constant 22.4 in cell B1.
2. Enter 10 in cell A5.
3. Write the formula '=A5+A$1' in cell A6 and press Enter. Drag the formula in cell A6 to A60. We get the volume values from 10 to 65 in the steps of 1.
4. Enter the formula '=B$1/A5^B$2' in cell B5 and drag it up to cell B60. These are then the values of pressure (in atm) for adiabatic change.
5. Plot the curve for pressure versus volume data using 'scatter with smooth lines' option. We see the adiabatic curve.
6. For comparison we may also plot the isothermal curve (Boyle's law curve) and compare the two curves.

We observe that the adiabatic curve falls faster than the adiabatic curve as volume increases, i.e., the pressure falls faster in adiabatic expansion than the thermal expansion.



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