

First Programming Assignment – Due Tuesday, February 7, 11:59 pm¹

Objective

This assignment provides an overview of various commands available through the Excel spreadsheet interface. Experience with these commands will be important for the remainder of the course where we will be using programming in Visual Basic for Applications (VBA) to interact with Excel.

Background

At low densities, real gas behavior approaches that of an ideal gas, which has a simple relationship between, pressure, P , volume, V , mass, m , Temperature, T , and molar mass, M :

$$PV = \frac{m}{M} R_u T$$

In this equation, R_u is the universal gas constant. The ratio m/M is called the amount of substance (or mole number), usually given the symbol n . The usual units for these variables in the SI unit system are kilopascals (kPa) for pressure, cubic meters (m^3) for volume, kelvins (K) for temperature², kilograms (kg) for mass, and kilograms/kilomole (kg/kmol) for molar mass. With these units the universal gas constant³ $R_u = 8.31447 \text{ kPa}\cdot\text{m}^3/\text{kmol}\cdot\text{K} = \text{kJ}/\text{kmol}\cdot\text{K}$. In engineering applications this equation is usually written in terms of the density, $\rho = m/V$, as follows.

$$\frac{MP}{R_u T} = \frac{m}{V} = \rho$$

The ratio of the universal gas constant to the molar mass is defined as the engineering gas constant, R . For the same set of units defined above, the units for the engineering gas constant (sometimes called the specific gas constant) are $\text{kJ}/\text{kg}\cdot\text{K}$.

$$R = \frac{R_u}{M}$$

With this definition, the density of an ideal gas is given by the following equation.

$$\rho = \frac{P}{RT}$$

Unlike the universal gas constant, the engineering gas constant is different for different gases. It may be readily found by dividing the universal gas constant by the molar mass of the desired gas or in tables of the engineering gas constant for different gases. This exercise uses the last two equations $R = R_u/M$ and $\rho = P/RT$ to obtain tables of the density of an ideal gas.

¹ It may be submitted by 11:59 pm, Friday, February 10, with a 30% penalty. No later submissions accepted.

² The absolute temperature in kelvins, K, is related to the usual temperature in degrees Celsius, °C, by the following formula: $T(\text{K}) = T(^{\circ}\text{C}) + 273.15$. Thus a temperature of 25°C is equivalent to 298.15 K.

³ The pressure unit of kilopascals (kPa) and the energy unit of kilojoules (kJ) are standard units in the SI system of units. By definition, $1 \text{ kPa}\cdot\text{m}^3 = 1 \text{ kJ}$.

Exercises

The exercises for this assignment use a variety of applications of the ideal gas equation with Excel spreadsheet formulas. Each exercise should be done on a separate worksheet in the same workbook.

First exercise. Set up a worksheet that has the following input data **in sequential rows**. Place the name of the data (not the symbol) in column A, the value of the data in column B, and the units in column C.

- Universal gas constant; 8.31447; kJ/kmol•K
- Substance; Air; (no entry in column C)
- Molar mass; 28.966; kg/kmol
- Pressure; 101.325; kPa (This is the standard atmospheric pressure.)
- Minimum temperature; 300; K
- Maximum temperature; 2500; K
- Temperature steps; 22; dimensionless

After you complete the input data, place the preliminary calculation results listed below in two rows following the data. Continue the pattern of values in column B, description in column A, and units in column C.

- Temperature increment; $\Delta T = (T_{\max} - T_{\min}) / N_{\text{steps}}$; K (N_{steps} is the number of temperature steps)
- The engineering gas constant = R_u/M ; kJ/kg•K

Create a table with two columns: temperature in kelvins and density in kg/m^3 . The first cell for each column should have the names; the second cell for each column should have the units.⁴ The third cell for the temperature column should be set equal to the user entered value for T_{\min} . The fourth cell for this column should be set equal to the previous value plus the temperature step ΔT . Copy this formula in the third cell into the fourth and subsequent cells until the final cell in the column is the maximum temperature. In the density column, enter the formula to compute the density for each temperature in the temperature column. Check your results.

Change the worksheet name to “Cells” by double-clicking the existing worksheet name (usually Sheet1) to select the entire name. Then simply type Cells and press Enter.

Second exercise. In this exercise you will learn the use of range names. This will make only a small change to the worksheet that you have used in the first exercise.

To create the worksheet for this exercise, make a copy of the worksheet from the first exercise and change its name to “Names”. To make this copy, right-click the name tab of the original worksheet and select **M**ove or **C**opy from the resulting menu. Once you have completed the copy operation, double click the tab of the new worksheet and change its sheet name to “Names”.

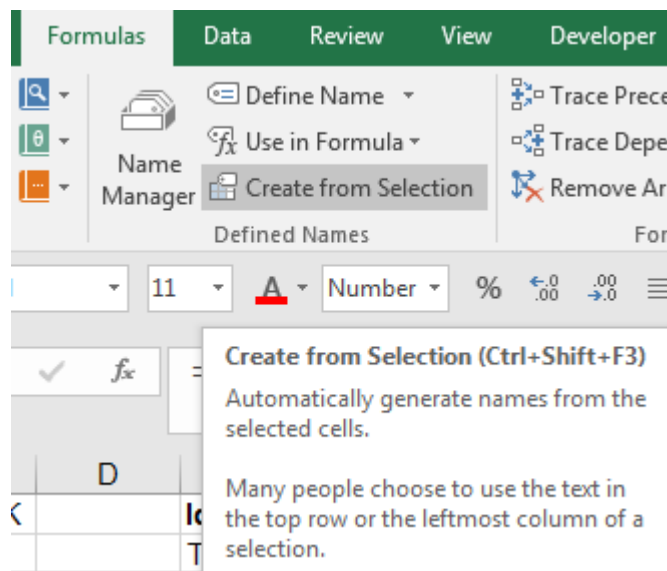
To start, create range names for each of the cells in column B that were specified by bullet points in the first exercise. The directions for doing this are shown below.

1. Select both the name column and the value column for the seven rows with initial data and preliminary results as shown in the figure at the right.

	A	B
1	Gas Constant	8.31447
2	Substance	Air
3	Molar Mass	28.966
4	Pressure	101.325
5	Tmin	300
6	Tmax	2500
7	Steps	22
8		
9	deltaT	100
10	EngrGasConst	0.2870

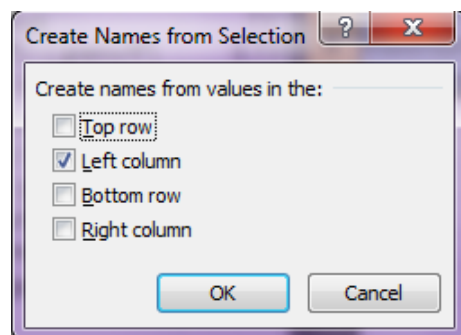
⁴ Although you can enter the density units as kg/m^3 , you can improve the appearance by entering the units as kg/m^3 . Use the following steps to do this. 1. Type kg/m^3 in the cell for the units. 2. Select the 3 with your mouse. 3. Right click the mouse to get a menu and select **F**ormat **C**ells... from that menu. 4. Check the **S**uperscript box in the resulting dialog and click **OK**.

- Next, click on the **Formula Tab**. In the resulting ribbon locate the **Defined Names Group**. In that group, click the **Create from Selection** menu item shown at the right. In this view, **Create from Selection** is shaded because the user has hovered the mouse over this option to display the help shown here. Clicking **Create from Selection** brings up the **Create Names from Selection** dialog box, shown at the right below.



- In this example, the **Create Names from Selection** dialog box already has the correct choice of creating the names from the values in the left column. Simply click **OK** and the nine range names will be created.

- To verify that these names have been created, you can select the **Name Manager** from the Defined Names group on the **Formula** tab or you can use the pull-down menu in the name box to display the names. In this example, the user selected cells A1:B10 to create the names shown in column A for the data entered in column B.

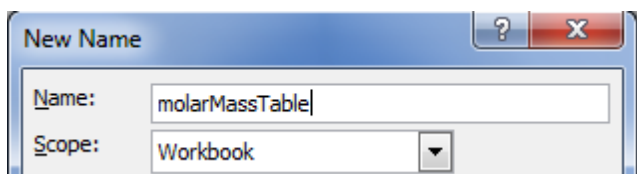


- Although you have created the names, Excel has not replaced them in the formulas. To do this, select all the formulas then choose the pulldown arrow from the right of the **Define Name** icon in the Defined Names group on the Formula tab. From the resulting submenu select **Apply Names**. In the resulting dialog box, select all the names in the **Apply names** list and click OK. (As an alternative you can delete the old formulas and enter them using point-and-click. This will apply the range names you just defined instead of the usual "A1" cell names.)

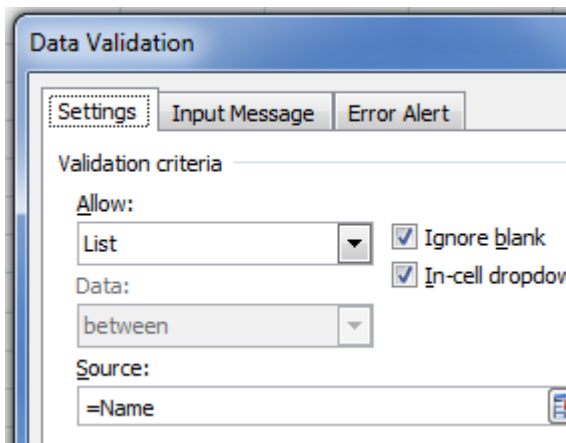
- Examine the formulas on the worksheet. All the cell references, in all the formulas, except for the temperature values should have been replaced by cell names. Verify that this is the case. Did you get the same results that you had previously?

Third exercise. In this exercise, you will create a data table with molar mass data that will allow users to select substances from a pull-down list and automatically find the molar mass from a table.

- Add a new worksheet to your workbook and change its name to dataTable. Then, copy the table on the next page to this new worksheet.
- Create names from the top row for all the data in each column. To do this select the entire table then click on **Create From Selection** in the Formula Tab.
- Make sure that only the option for top row is selected in the **Create Names From Selection** dialog box then click OK.
- You can use the Name Manager to show that the names, **Name** and **molarMass** now refer, respectively, to the first column and second column of the table, not including the first row (**Name** is the range A2:A39 and **molarMass** is the range B2:B39).
- Select the entire table except for the header rows (should be the range A2:B39), and click **Define Name** from the Defined Names group on the Data tab. In the resulting **New Name** dialog enter the name molarMassTable in the **Name** box as shown at the right.



- Go to the first worksheet named "Cells", and select cell B2 which should have the text "Air" as its entry.
- Click on **Data Validation** in the **Data Tools** group of the **Data** tab. In the resulting dialog box, select **List** from the **Allow:** menu and in the **Source:** box enter the formula "=Name". The result should look like the dialog below. After you Click **OK**, you should see a pull down arrow next to cell B2. This will allow you to select any name in the data table.



- You now have a way to choose the substance. To get the correct molar mass enter the following formula in cell B3: =VLOOKUP(B2,molarMassTable,2,FALSE)
- Select cell B2 and use the pull-down arrow to select other substances. Notice that the correct molar mass now appears in cell B3 when you select a substance in cell B2.
- Copy the contents from B2:B3 on the "Cells" worksheet to B2:B3 on the "Names" worksheet; this copies the data validation from cell B2 as well as the formula from cell B3.
- Edit the formula in cell B3 on the "Names" worksheet to replace B2 in the formula with the range name for cell B2.

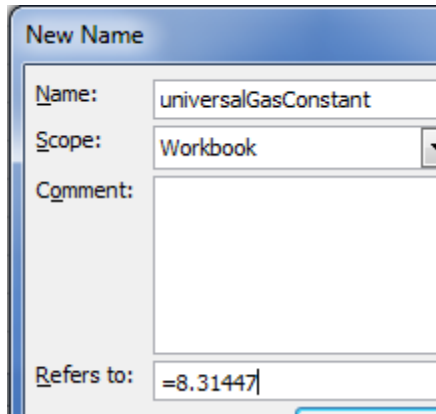
You should now be able to generate a table for density as a function of temperature, at fixed pressure, for any input gas species from the data table.

Fourth exercise. In this exercise, you will create a two-way data table giving density as a function of temperature and pressure. Make a copy of the "Names" worksheet that you used for Exercise two and name it two-way.

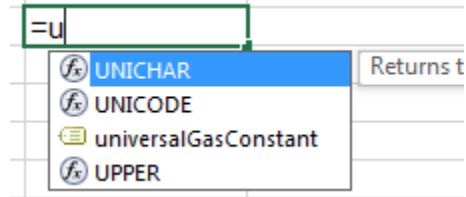
As part of this exercise you will create a named constant. Although we have discussed creating names for cells, it is also possible to create a name for a constant. Here you will create a name to refer to the universal gas constant. The instructions for this are shown below. A view of the New Name dialog for these instructions is on the next page.

- Click on **Define Name** in the Defined Names group on the Data tab.
- In the resulting New Name dialog box enter the name as universalGasConstant in the **Name:** box and the equation "=8.3144621" in the **Refers to:** box to give the result shown below. Click **OK** to define the name.

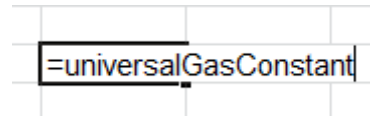
Name	molarMass
Acetylene	26.038
Air	28.9652
Ammonia	17.031
Argon	39.948
Benzene	78.114
Butadiene	54.092
Butane	58.124
Carbon Dioxide	44.009
Carbon Monoxide	28.010
Chlorine	70.90
Ethane	30.070
Ethyl Chloride	64.512
Ethylene	28.054
Fluorine	37.996
Helium	4.0026
Hexane	86.178
Hydrogen Chloride	36.458
Hydrogen Sulfide	34.076
Hydrogen	2.016
Isobutene	56.108
Krypton	83.798
Methane	16.043
Methyl Chloride	50.485
Neon	20.180
Nitric Oxide	30.006
Nitrogen	28.014
Nitrogen Dioxide	46.005
Nitrous Oxide	44.013
Octane	114.232
Oxygen	31.998
Ozone	47.997
Pentane	72.151
Propane	44.097
Propylene	42.081
Sulfur Dioxide	64.058
Toluene	92.141
Water	18.015
Xenon	131.29



You should have noticed that when you type an equal sign and the start of the name of a function, Excel provides a list of possible entries that start with the letter(s) you type. This list of possible entries will also include any range names that have been defined. To demonstrate this, select a blank cell and type “=u”. When you do this, you should get a list of four possible names as shown at the right below. (The capitalized names are the names of functions.)



If you single click a function name, the background of the name turns blue and a description of the function appears to the right. Double clicking any name inserts that name into the cell preceded by an equal sign. If the name is a function, you have to complete the entry of the function arguments, if any, and the closing parentheses for the argument list. For a named constant like universalGasConstant, the name will be entered into the cell as shown at the right. For both a function entry and a named constant entry, you must press “Enter” to complete your entry. When you do this the calculated function value (or the value of the named constant) will appear in the cell.



This shows that you can define a constant that you need in several places in a workbook as a named constant and you can easily enter it in a cell. This might be done for an overhead rate used in company proposals. If this “constant” were changed it could be updated in the Name Manager.

You are now ready to proceed with the generation of the two way table.

Create the cell entries shown at the right on the new worksheet named two-way table that you created before defining the named constant. The cells with the substance name and molar mass should be the ones you developed in the previous exercise where the substance name comes from a pull-down list and the molar mass comes from the VLOOKUP command. Name all the cells in the range B1:B11 using the **Create from Selection** command. All the cells, except for the pFactor cell are similar to those you have used previously. Because pressure is a variable, whose range is usually two or three orders of magnitude, the successive values of pressure are computed by a constant *multiplicative* factor as shown below.

	A	B	C
1	Substance	Hydrogen	
2	Molar Mass	2.01588	kg/kmol
3	Tmin	300	K
4	Tmax	2500	K
5	Tsteps	22	
6	Pmin	100	kPa
7	Pmax	10000	kPa
8	Psteps	12	
9	deltaT	100	K
10	pFactor	1.467799	
11	EngrGasC	4.124487	kJ/kmol×K

$$p_{k+1} = f_{pressure} p_k$$

In this equation, $f_{pressure}$, which is called the pressure factor and has the abbreviation pFactor in cell A10; it is computed from the following equation, where N_{pSteps} , the number of pressure steps, has the abbreviation Psteps in cell A8.

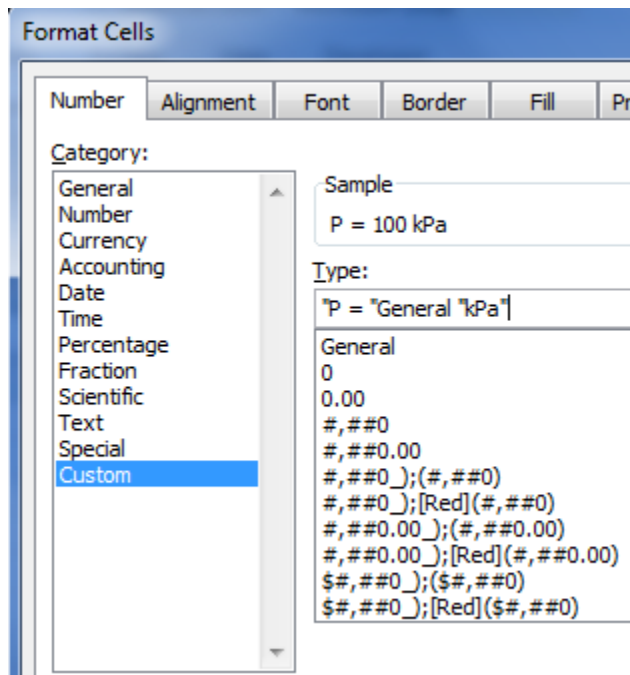
$$f_{pressure} = \left(\frac{p_{max}}{p_{min}} \right)^{1/N_{pSteps}}$$

Use this equation in cell B10.

The goal this exercise is to create a two-dimensional table of ideal gas density (in kg/m^3) as a function of temperature and pressure. A view of the final table is shown at the right. There are several steps to the creation of this table. They involve a combination of numerical calculations and formatting. The numerical calculations are generated during steps 1 to 5; the remainder of the steps are formatting.

1. Repeat the process used in earlier exercises to set the initial temperature in the table equal to T_{\min} and to increment the temperatures in the column by the temperature increment.
2. Set the initial pressure in the row of pressures equal to P_{\min} .
3. Set each new entry in the row of pressures equal to the previous entry times the pFactor term.
4. Write the density equation, $\rho = P/(RT)$ for the lowest pressure and the lowest temperature so that the pressure value always comes from the same row and the temperature value always comes from the same column. (Recall that the notation \$A1 gives a fixed column and a relative row; the notation A\$1 gives a fixed row and a relative column.)
5. Copy the formula you just wrote to all the cells in the table. Select those cells and get a common format for the density values. This completes the numerical calculations; the remaining steps are for formatting the leftmost (temperature) column and the top (pressure) row.
6. Select all the filled cells in the pressure row, right click this selection, and choose **Format Cells** from the resulting menu. In the resulting dialog. Click the **Number** tab at the top, if it is not already displayed. Locate the text box under the heading **Type:** and type "P = "General "kPa" in that text box. The result should look like the one at the right when you have finished typing. Click **OK** to format the actual cells.
7. Repeat this custom format process with the temperature column.
8. The table header is obtained by the following text equation:⁵="Density table for " & Substance & " (kg/m" & CHAR(179) & ")"

Density table for Hydrogen (kg/m^3)			
	P = 100 kPa	P = 147 kPa	P = 215 kPa
T = 300 K	0.0808181	0.1186248	0.1741174
T = 400 K	0.0606136	0.0889686	0.1305881
T = 500 K	0.0484909	0.0711749	0.1044704
T = 600 K	0.0404091	0.0593124	0.0870587
T = 700 K	0.0346363	0.0508392	0.0746217
T = 800 K	0.0303068	0.0444843	0.0652940



Fifth Exercise. Create a plot of density as a function of temperature with pressure as a parameter. Your plot should have a chart title, axis titles for both the temperature and density axis, and a legend. You should be able to have a chart title formed by an equation, like the equation used for the table title, that always gives the correct substance in the title.

⁵ The header you type is actually an equation that uses operations on text values. The basic parts are string constants, delineated by quotation marks, and the concatenation operator, &, which joins two strings. For example, if you typed = "Mechanical" & " Engineering" in a cell and pressed enter, the cell would display **Mechanical Engineering**. The word Substance in this text formula is the name of the cell that contains the substance name. (Once you have the header typed properly you can change the substance name and the header (as well as all the numerical calculations) will change. Finally the CHAR() function is used to display certain characters that cannot easily be typed. What do you think the CHAR(179) produces?