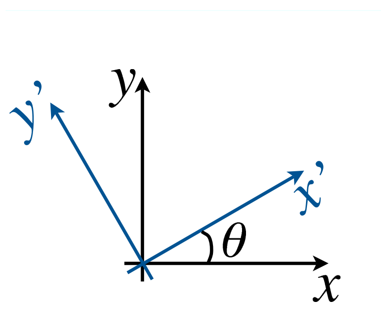
CHEN 1703 - HOMEWORK 4

Submit your MATLAB solutions via the course web site. Be sure to include your name and UNID in your m-file. Submit each solution seperately. Also be sure to document your solutions well. Include a description of the equations you are solving. To receive full credit, your m-file must run. See the tutorial on naming m-files for more information.

Problem 1 (10 points)

In class we mentioned that the following transformation can be used to obtain the coordinates of a point in the (x', y') coordinate system given the coordinates of a point in the (x, y) coordinate system:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{pmatrix} x \\ y \end{pmatrix}. \quad (1)$$



1. (3 pts) Given the point $(x, y) = (5, 3)$, obtain the coordinates for the point (x', y'), assuming that the (x', y') coordinate system is rotated 65° from the (x, y) coordinate system.
2. Given a point in $(x', y') = (8, 10)$, determine the value of this point in the (x, y) coordinate system, assuming $\theta = 72°$. Do this two ways:
   (a) (3 pts) Using MATLAB to solve equations (1).
   (b) (4 pts) Solve equations (1) by hand to obtain equations for x and y in terms of x' and y' and enter the result into your MATLAB file.

   Print the results to the command window.

A sample output:

```
For theta=65, the point (x,y)=(5,3) becomes
     4.8320
   -3.2637
For theta=72, the point (x',y')=(8,10) becomes:
   -7.0384
   10.6986
Solving by hand, the point (x',y')=(8,10) becomes:
   -7.0384
   10.6986
```

Note that x' can be printed out as demonstrated by the following command:

```
disp('For theta=72, the point (x'',y'')=(8,10) becomes:');
```

Problem 2 (5 points)

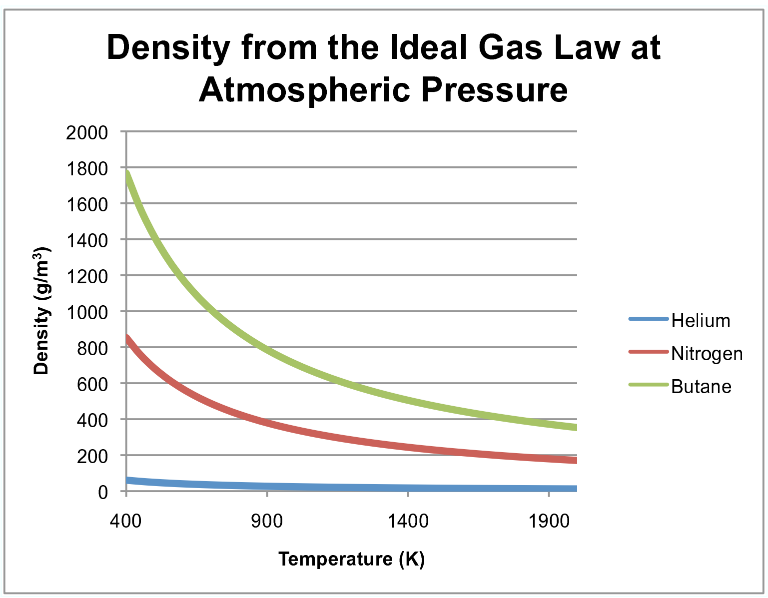
The ideal gas law can be written as $pV = nRT$. Dividing by n, we find $p\hat{V} = RT$, where $\hat{V}$ is the *molar volume* (volume occupied by a single mole of a gas). We can also write the ideal gas law in terms of the density (mass per unit volume),

$$\rho = \frac{p\,W}{R\,T},$$

where W is the molecular weight of the gas and R is the universal gas contant, $R = 8.314\,\frac{\mathrm{m^3 \cdot Pa}}{\mathrm{mol \cdot K}}$. Using Excel, plot the density as a function of temperature for the following compounds at $p = 101325\,\mathrm{Pa}$ (atmospheric pressure):

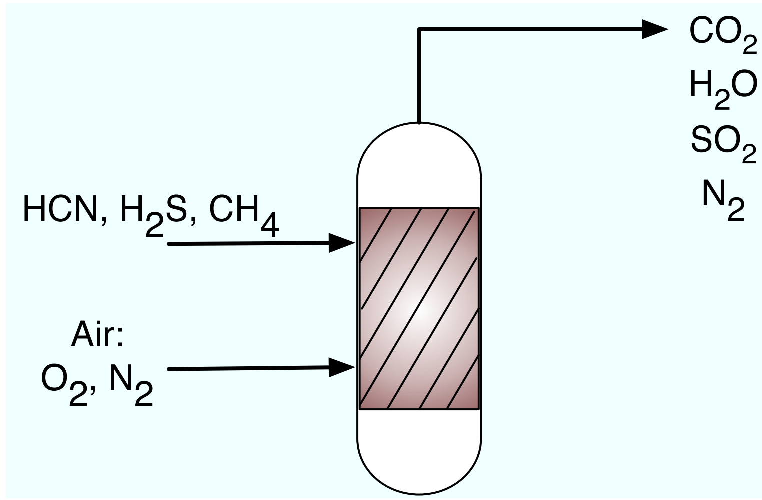
- Helium (He)
- Nitrogen (N_2)
- Butane (C_4H_{10})

Plot this over the temperature range $T = [400, 2000]$ K. Be sure to label your plot, and include units on your numbers in your spreadsheet. Pay particular attention to the units of density. Your plot should look something like the following:



Problem 3 (10 points)

Consider the following problem (a modification of what we discussed in class):



Your company needs to eliminate toxins (Hydrogen Sulfide and Cyanide) that are a byproduct from one of its processes. You are currently using natural gas (primarily composed of CH_4) to incinerate these toxins. You know the molar flow rates of CH_4, SO_2, and H_2O. You are asked to determine the molar flow rates of all of the remaining species.

Assuming that complete combustion occurs, you know that

$$a\,CH_4 + b\,HCN + d\,H_2S + e\,(0.21\,O_2 + 0.79\,N_2) \longrightarrow f\,CO_2 + g\,H_2O + i\,SO_2 + j\,N_2,$$

Based on balancing the number of moles of each element, you arrive at the following equations:

$$\begin{aligned} a + b &= f \\ 4a + b + 2d &= 2g \\ 0.42e &= 2f + g + 2i \\ b + 1.58e &= 2j \\ d &= i \end{aligned}$$

You measure the flow rates of CH_4, SO_2, and H_2O to obtain

$$\begin{aligned} a &= 430\,\frac{\text{kmol}}{\text{hr}}, \\ i &= 76\,\frac{\text{kmol}}{\text{hr}}, \\ g &= 1200\,\frac{\text{kmol}}{\text{hr}}. \end{aligned}$$

1. (5 pts) In your MATLAB code, rewrite the above equations so that the known quantities are on the right-hand side and the unknown quantities are on the left-hand side. Do this in your comments for your m-file.

2. (5 pts) Solve for the MASS flow rates of Air, CO_2, HCN and H_2S, and print them to the screen. You MUST use a matrix formulation to solve this problem.

HINTS:

1. See the example file from what we did in class for help on what I expect for this problem.
2. Don't forget to convert molar flow rates to mass flow rates. You will need the molecular weight of each compound for this. Note that a molecular weight in $\frac{g}{mol}$ is the same as one in $\frac{kg}{kmol}$. Thus, if you multiply the molar flow rate by a molecular weight then you will have the mass flow rate in $\frac{kg}{hr}$.
3. The molecular weight of air is approximately 28.85 $\frac{kg}{kmol}$.

My solution provides the following output:

```
The flow rate of HCN (kg/hr) is:
   1.4269e+04
The flow rate of H2S (kg/hr) is:
   2.5901e+03
The flow rate of Air (kg/hr) is:
   2.2448e+05
The flow rate of CO2 (kg/hr) is:
   4.2162e+04
```

Suggested Exercises (do not submit)

Given $A = \begin{bmatrix} 1 & 7 \\ 4 & 3 \\ 5 & 9 \end{bmatrix}$, $B = \begin{bmatrix} 3 & 4 & 1 \\ 10 & 2 & 8 \end{bmatrix}$, $c = \begin{bmatrix} 5 \\ 6 \\ 2 \end{bmatrix}$,

Indicate whether the following products can be formed. If they can be formed, calculate the result. Do this *by hand* and *using Matlab*.

1. AB
2. Ac
3. $A^{\mathsf{T}}c$
4. BA
5. BC

Given the arrays defined above, show the result of the following Matlab commands. If a command is not valid, indicate that. Note: see if you can get this right before trying it in Matlab. Then check yourself by using Matlab.

1. `A.*B'`
2. `A*B`
3. `A(:,2).*c`
4. `B(1,:)*c`
5. `B(1,:).*c`