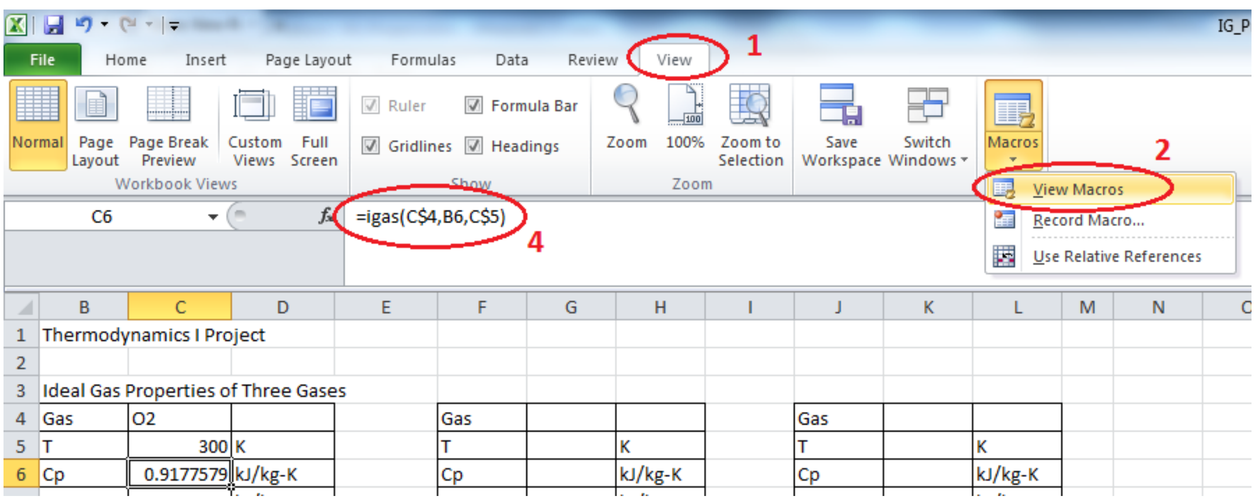
Thermodynamics I Semester Project for Spring 2015

Due: Beginning of class on Thursday (3/26)

Groups: Four students per group

Assignment: Create functions in Excel that allow the user to determine ideal gas properties of three different assigned gases (including O_2) without the use of tables. The properties must account for variable specific heats as is done in the tables. To demonstrate that your functions are correct you must use the functions to populate all the cells on the given spreadsheet template. The template has the function for Cp already completed and the Cp values calculated on the spreadsheet determined with a call to the function igas { *i.e.*, formula = igas(Gas, Desired Property, Given Temperature) }.

Instructions: Download and open the project template (Project Template.xlsm) and select the "View" tab at the top of the spreadsheet (see step 1 below). Select view macros (see step 2 below) and edit Module 1 according to the instructions there highlighted in green. The appropriate expressions for each calculated property are given below. Return to the spreadsheet and make appropriate calls to the function (see step 4 below) in each cell to complete the spreadsheet.



$$\mathbf{Cp} = R\left(\alpha + \beta T + \gamma T^2 + \delta T^3 + \varepsilon T^4 + \phi T^5\right)$$

$$Cp = \frac{dh}{dT} \quad \rightarrow \quad \Delta h = \int Cp\, dT$$

$$h - h_{ref} = R\int\left(\alpha + \beta T + \gamma T^2 + \delta T^3 + \varepsilon T^4 + \phi T^5\right) dt$$

$$\mathbf{h} = R*\left(\alpha T + \frac{\beta}{2}T^2 + \frac{\gamma}{3}T^3 + \frac{\delta}{4}T^4 + \frac{\varepsilon}{5}T^5 + \frac{\phi}{6}T^6\right) + \kappa$$

$$\mathbf{u} = h - RT$$

$$\mathbf{s^o} = \int \frac{Cp}{T}\, dT = R*\left(\alpha \ln(T) + \beta T + \frac{\gamma}{2}T^2 + \frac{\delta}{3}T^3 + \frac{\varepsilon}{4}T^4 + \frac{\phi}{5}T^5\right) + \kappa_2$$

$$\mathbf{P_r} = \frac{\exp\left[s^o/R\right]}{\kappa_3} \quad , \quad \mathbf{V_r} = \frac{RT}{P_r}\kappa_4$$

Excel Program – Macro (Written by Dr. Crown and modified by you)

```
Dim R, MW, iga, igb, igc, igd, ige, igf, kh, kso, kpr, kvr As Double
Sub Macro1()
' Modify the program below to include different gases and properties other than Cp
End Sub
Public Function IGas(Gas, Gp, Optional T)
 Gp = LCase(Gp)
 If (Gp = "so") Then Gp = "s0"
 If (Gp = "r") Then Gp = "R"
 'I already entered the correct constants for the first gas (Oxygen)
 If Gas = "O2" Then
  MW = 32
  iga = 3.626
  igb = -0.001878
  igc = 0.000007055
  igd = -0.000000006764
  ige = 0.000000000002156
  igf = 0
  kh = -0.8776
  kso = -3
  kpr = 2000
  kvr = 1
 End If
 'Change the gas below and enter the appropriate constants
 If Gas = "X2" Then
  MW = 1
  iga = 0
  igb = 0
  igc = 0
  igd = 0
  ige = 0
  igf = 0
  kh = 0
  kso = 0
  kpr = 1
  kvr = 1
 End If
 'Change the gas below and enter the appropriate constants
 If Gas = "XY2" Then
  MW = 1
  iga = 0
  igb = 0
  igc = 0
  igd = 0
  ige = 0
  igf = 0
  kh = 0
  kso = 0
  kpr = 1
  kvr = 1
 End If
 'Do not change anything here
 R = 8.314 / MW
 If Gp = "cp" Then IGas = Cp(T)
 If Gp = "h" Then IGas = h(T)
```

```
  If Gp = "u" Then IGas = u(T)
  If Gp = "s0" Then IGas = so(T)
  If Gp = "pr" Then IGas = Pr(T)
  If Gp = "vr" Then IGas = Vr(T)
  If Gp = "R" Then IGas = R
End Function
Public Function Cp(T)
  'This function for Cp is correct and does not need to be modified.
  Cp = R * (iga + igb * T + igc * T ^ 2 + igd * T ^ 3 + ige * T ^ 4 + igf * T ^ 5)
End Function
Public Function h(T)
  'Enter the correct expression for specific enthalpy on the line below.
  h = 1
End Function
Public Function u(T)
  'Enter the correct expression for specific internal energy on the line below.
  u = 1
End Function
Public Function so(T)
  'Enter the correct expression for the temperature part of specific entropy (So)on the line below.
  so = 1
End Function
Public Function Pr(T)
  'Enter the correct expression for relative pressure on the line below.
  Pr = 1
End Function
Public Function Vr(T)
  'Enter the correct expression for relative specific volume on the line below.
  Vr = 1
End Function
Public Function InvGas(Gas, Gp, Gv)
'This function does not need to me modified.  This function finds the Temperature given any another property and the value for that property.
   GX = 300
   SX = 100
   CY = IGas(Gas, Gp, GX)
   ErrMax = (Gv / 100000#)
   STEP = SX
   KK = 0
   Kmax = 500
   Do
      While ((CY - Gv) > ErrMax)
        GX = GX - STEP
        CY = IGas(Gas, Gp, GX)
        If ((CY - Gv) < 0#) Then STEP = STEP / 2
        If (KK > Kmax) Then Exit Do Else KK = KK + 1
      Wend
      While ((CY - Gv) < (-ErrMax))
        GX = GX + STEP
        CY = IGas(Gas, Gp, GX)
        If ((-Gv) > 0#) Then STEP = STEP / 2
        If (KK > Kmax) Then Exit Do Else KK = KK + 1
      Wend
   Loop While (Abs(CY - Gv) > ErrMax)
   InvGas = GX
End Function
```

F2012_Project_solution.xlsm - Microsoft Excel

Thermodynamics I Project

Ideal Gas Properties of Three Gases

Gas	O2	
T	300	K
Cp	0.9177579	kJ/kg-K
h	0	kJ/kg
u	0	kJ/kg
so	0	kJ/kg-K
Pr	3.4273561	
Vr	22.741655	

Gas		
T		K
Cp		kJ/kg-K
h		kJ/kg
u		kJ/kg
so		kJ/kg-K
Pr		
Vr		

Gas		
T		K
Cp		kJ/kg-K
H		kJ/kg
U		kJ/kg
So		kJ/kg-K
Pr		
Vr		

Ideal Gas Table

Gas	O2					
T	Cp	h	u	so	Pr	Vr
(K)	(kJ/kg-K)	(kJ/kg)	(kJ/kg)	(kJ/kg-K)		
300	0.9177579	0	0	0	3.427356	22.74166
350	0.9289036	0	0	0	5.926376	15.34401
400	0.9420535	0	0	0	9.583656	10.84398
450	0.9565198	0	0	0	14.73617	7.93392
500	0.9716988	0	0	0	21.78468	5.963192
550	0.9870704	0	0	0	31.20078	4.579913
600	1.0021991	0	0	0	43.53313	3.580893
650	1.016733	0	0	0	59.41261	2.842462
700	1.0304043	0	0	0	79.55627	2.286039
750	1.0430295	0	0	0	104.7701	1.859875
800	1.0545087	0	0	0	135.9512	1.528857
850	1.0648263	0	0	0	174.0894	1.268547
900	1.0740507	0	0	0	220.2698	1.061567
950	1.0823343	0	0	0	275.6778	0.895327
1000	1.0899134	0	0	0	341.6077	0.760558

Homework Problem #1: A piston cylinder assembly contains a fixed amount of a gas at a given temperature and pressure. The gas is brought to a final given temperature at constant pressure. Determine the heat transfer during the process.

Given			Find		
Gas=	O2		u1=	195.0563	kJ
m=	1.96	kg	u2=	686.374	kJ
T1=	300	K	ΔU=	962.9827	kJ
P1=	200	kPa	W=	335.075	kJ
T2=	958	K	Q=	1298.058	kJ

Homework Problem #2: A piston cylinder assembly contains a fixed amount of a gas at a given temperature and pressure. For a specified quanity of heat transfer to the system, determine the final temperature.

Given			Find		
Gas=	O2		Δh=	662.2743	kJ
m=	1.96	kg	h1=	273	kJ
T1=	300	K	h2=	935.2744	kJ
P1=	200	kPa	T2=	958.0078	K
Q=	1298.058	kJ			

Ideal Gas

Ready