AME 513	Assigned: Saturday 11/10/2012
Problem Set #3	• **Due Wednesday 11/21/2012 at 4:30 pm (return by Tuesday in the drop box in OHE 430N, or email by Wednesday)** • **Email to the grader (Thada Suksila) at ame513_fall2012@yahoo.com or fax to 213-740-8071 if you're off campus** • **DEN students submit through the usual channels**

Textbook problems:

8.6 (Bunsen flames)
8.16 (Ignition)
16.1 (Detonations)
16.5 (Detonations)

Other problems:

PDR1. (Detonations)

By combining Equations 1 – 5 shown on pages 9 – 10 of Lecture 8, show that the Chapman-Jouget detonation velocity is that given on page 10 of Lecture 8.

PDR2. (Burning velocities)

a. Plot $\ln(S_L)$ vs. $1/T_{ad}$ for lean to stoichiometric 1 atm methane-air flames using the S_L data given in the lecture notes or any other reference of your choice.
b. From a least-square fit to this data, estimate the effective overall activation energy E_a (note that the slope of the above plot is $-E/2\Re T$)
c. Using S_L for the stoichiometric methane-air mixture, estimate the pre-exponential term Z using the expression for S_L from Mitani (1980) given in the lecture notes
d. Compare your pre-exponential term to those in Table 5.1. Why is your value so different?
e. Use the pre-exponential term and activation energy you calculated to predict the burning velocity for
    1. Methane-air, 1 atm, equivalence ratio 0.7
    2. Methane-air, 3 atm, equivalence ratio 1
f. Find data on S_L vs. pressure for stoichiometric methane-air mixtures, for example Egolfopoulos et al., Combustion and Flame, Volume 76, Issues 3–4, June 1989, Pages 375–391.
    1. Plot $\log(S_L)$ vs. $\log(P)$ and determine the order of reaction.
    2. Compare this to the order of reaction implied by the data in Table 5.1.
    3. What order of reaction is assumed in the Mitani expression as applied to methane-air mixtures?

PDR3. (Flammability limits)

For each of the following extinction limit mechanisms

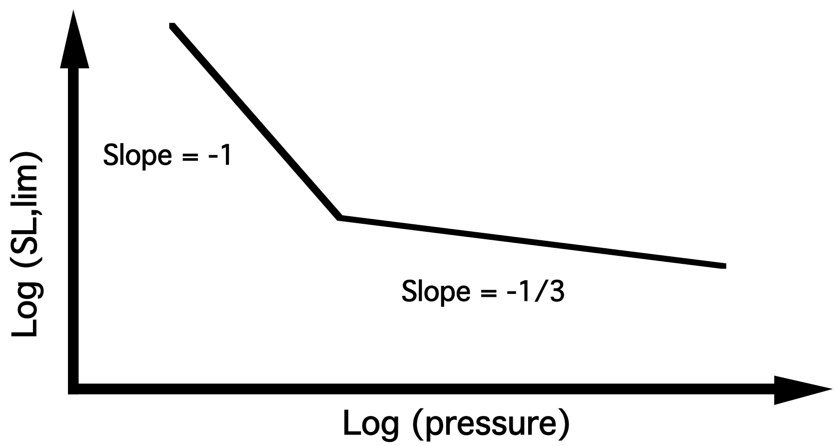
- Conduction heat losses to a tube wall
- Buoyancy-induced limit for upward propagation in a tube
- Buoyancy-induced limit for downward propagation in a tube
- Radiation heat loss

answer the following two questions: (1) Which would extinguish at higher S_L – CO_2 or N_2-diluted stoichiometric CH_4-O_2 mixtures? (2) Which would extinguish at higher adiabatic flame temperature?

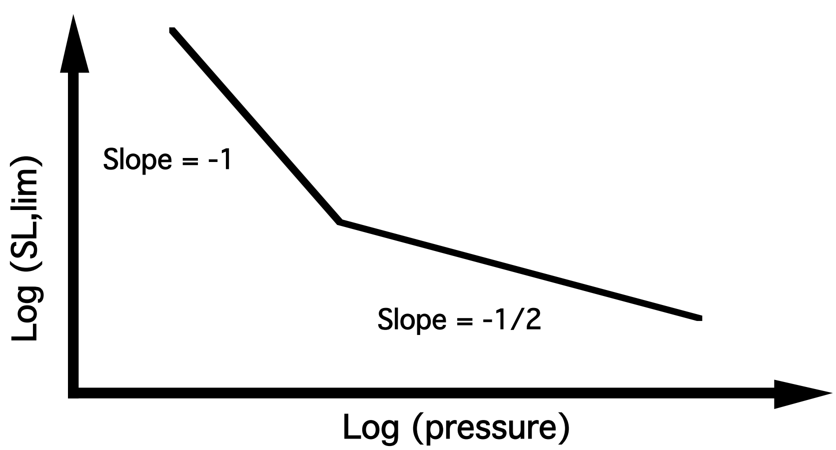
You'll need a source of data on thermal conductivity, thermal diffusivity, heat capacity, etc., of gas mixtures; use either GASEQ or the Colorado State website.

<u>PDR4. (Flammability limits)</u>

a) Explain the following experimental data taken for **downward** propagating flames in CH_4-air mixtures in a 5 cm diameter tube **at earth gravity**. At approximately what pressure and what $S_{L,lim}$ would the "knee" of this curve occur?



b) Explain the following experimental data taken for downward propagating flames in CH_4-air mixtures in a 5 cm diameter tube **at zero-gravity**. At approximately what pressure and what $S_{L,lim}$ would the "knee" of this curve occur?



Possibly useful information: $g = 980\ cm/sec^2$; $T_{ad} \approx 1500K$; $T_o \approx 300K$; α (air, 1 atm) = 0.2 cm^2/sec; $\alpha \sim P^{-1}$; k(air, 1 atm) = 0.026 W/mK; $k \sim P^0$; $\beta \approx 14$ = constant; Λ of CH_4-air combustion products, 1 atm) = $10^6\ W/m^3$; $\Lambda \sim P^1$.

PDR5. (Ignition)

For CH_4-air mixtures with initial temperature 300K and pressure 1 atm

a) Calculate and plot the adiabatic flame temperature as a function of equivalence ratio (ϕ) using GASEQ or some other method of your choice
b) Using the Mitani relation calculate and plot S_L and $\delta = \alpha/S_L$ as a function of ϕ for the range $0.5 < \phi < 1.5$.
c) From this information calculate and plot the minimum ignition energy as a function of ϕ.
d) Compare this to the experimental results of Lewis and von Elbe. To what do you attribute the differences?