

AME 436	Assigned: Thursday 2/12/09
Problem Set #2	<ul style="list-style-type: none"> • Due Friday 2/20/09 at 4:30 pm in OHE 430J • Email to the grader (Thada Suksila, suksila@usc.edu) or fax to 213-740-8071 if you're off campus • DEN students submit through the usual channels

Problem #1 (15 points)

Using the Zeldovich equation for burning velocity (S_L), and typical “baseline” values of ambient temperature (T_∞), adiabatic flame temperature (T_{ad}), order of reaction (n) and activation energy (E), answer the following questions:

- How does the reactant temperature T_∞ affect S_L , everything else (including the product temperature T_{ad}) held constant? That is, will a 10% increase in T_∞ cause a more or less than 10% increase/decrease in S_L ?
- How does T_{ad} affect S_L , everything else (including T_∞) held constant? That is, will a 10% increase in T_∞ cause a more or less than 10% increase/decrease in S_L ?
- How does the concentration of fuel in the reactants affect S_L , everything else (including T_∞ and T_{ad}) held constant? That is, will a 10% increase in the concentration of fuel in the reactants cause a more or less than 10% increase/decrease in S_L ?
- How does the pressure of the reactants affect S_L ? That is, will a 10% increase in pressure cause a more or less than 10% increase/decrease in S_L ?

Problem #2 (15 points)

For the homogeneous reaction/ignition problem discussed in class, write a short computer program to solve the differential equation that results. You can use the [simple Excel sheet](#) I created (or you build your own in Excel, Matlab, etc.) Using your program, and taking into account the definitions of the dimensionless input parameters ϕ (phi), β (beta) and H answer the following:

- How does the reactant temperature T_∞ affect the dimensional time for ignition to occur (arbitrarily defined as 90% completion of reaction), everything else (including the product temperature T_{ad}) held constant? That is, will a 10% increase in T_∞ cause a more or less than 10% increase/decrease in the dimensional time for ignition to occur? How does the activation energy affect your conclusion, that is, will a 10% increase in E change the sensitivity of ignition time to T_∞ ?
- How does T_{ad} affect the dimensional time for ignition to occur, everything else (including T_∞) held constant? How does the activation energy affect your conclusion? How does the activation energy affect your conclusion, that is, will a 10% increase in E change the sensitivity of ignition time to T_{ad} ?

- c) How does the concentration of fuel in the reactants affect the dimensional time for ignition to occur?
- d) How does the pressure of the reactants affect the dimensional time for ignition to occur?

Problem #3 (15 points)

- a) Calculate and plot the homogeneous ignition time (default definition is time to reach initial temperature + 400K) at constant pressure as a function of temperature for a stoichiometric $H_2 - O_2$ mixture at 1 atm over the initial temperature range 800K - 1500K using the on-line chemical kinetics calculator at <http://navier.engr.colostate.edu/tools/homkin.html>. Use for 800K the following parameters: integration time 10 seconds, time interval 0.1 seconds, HydrogenOxygen mechanism. For higher initial temperatures the time to ignition will decrease and you'll have to decrease the integration time and time interval.
- b) From this information, estimate the effective activation energy of $H_2 - O_2$ combustion from a plot of $\ln(\text{ignition time})$ vs. $1/T_\infty$ (the slope of this plot is E/R). (Note: the slope won't be very constant; there will be a "kink" near 1000K because of a change in the dominant chemical reactions at that temperature.)
- c) Calculate and plot the ignition time at constant pressure as a function of pressure for a stoichiometric $H_2 - O_2$ mixture at 800K over the pressure range 1 atm - 10 atm using the on-line chemical kinetics calculator.
- d) From this information, estimate the effective order of reaction (n) of $H_2 - O_2$ combustion from a plot of ignition time vs. pressure (the slope of this plot on a log-log scale is $1-n$)

Problem #4 (15 points)

Using the d^2 law for droplet burning, explain following.

- a) How does the reactant temperature T_∞ affect the total droplet burning time, everything else (including the product temperature T_{ad}) held constant? How does the activation energy affect your conclusion, that is, will a 10% increase in E change the sensitivity of droplet burning time to T_∞ ?
- b) How does T_{ad} affect the total droplet burning time, everything else (including T_∞) held constant? How does the activation energy affect your conclusion, that is, will a 10% increase in E change the sensitivity of droplet burning time to T_{ad} ?
- c) How does the concentration of oxygen in the atmosphere affect the total droplet burning time?
- d) How does the pressure of the reactants affect the total droplet burning time?

Problem #5 (from a previous midterm exam, continued from Homework #1) (10 points)

On Jupiter is an atmosphere of 60% hydrogen (H_2) and 40% helium (He) (60%/40% on a molar

basis) at a pressure of 0.2 MPa (2 earth atmospheres) total pressure at 200K . Deep underground are deposits of pure O₂ that the Jovians (residents of Jupiter) pump out of the ground. Unfortunately, most of the O₂ wells are located in politically unstable regions of Jupiter, so this O₂ is a valuable resource which they call “fuel.” The hydrogen/helium mixture in the atmosphere, which they call “air,” is “free” as far as Jovians are concerned.

Thermodynamic data: average mixture properties $\gamma = 1.3$, $R = 300 \text{ J/kgK}$, $C_v = 1000 \text{ J/kgK}$

	H ₂	O ₂	He	H ₂ O
Δh_f° (kJ/mole)	0	0	0	-241.83
Molecular weight (g/mole)	2	32	4	18

Estimate the BMEP of stoichiometric premixed-charge naturally-aspirated Jovian engines at wide-open throttle, with compression ratio 8.

Problem #6 (from a previous midterm exam) (15 points)

Ronney Oil and Gas Company claims to have developed a fuel, called PDR[®], that has all the same thermodynamic properties, transport properties, chemical reaction rate parameters, etc. as octane except that PDR[®] has **10% higher heating value per unit mass** than octane. If PDR[®] fuel were used instead of octane, how would each of the following be affected? In particular, state whether each of the above will increase or decrease or remain constant, and by less than 10%, more than, or exactly 10% **and briefly explain why.**

- The laminar burning velocity (S_L) of a premixed flame in a stoichiometric mixture (hint: how does the 10% higher heating value change the adiabatic flame temperature?)
- The burning rate constant (K) of a liquid fuel droplet
- BMEP of a premixed-charge engine burning a stoichiometric mixture

Problem #7 (from a previous final exam) (15 points)

A four-stroke gasoline engine with a displacement of 3.05 liters is tested in the laboratory at 3000 RPM and found to have the following performance characteristics: net IMEP 107.9 pounds per square inch, 70.32 brake horsepower, fuel flow rate 16.66 kg/hr, and air flow rate 269.6 kg/hr. The fuel is iso-octane, C₈H₁₈ (heating value 4.3 x 10⁷ J/kg.) The ambient air temperature is 295K. The intake pressure gauge is broken, so the intake pressure is not known. Determine the following performance parameters.

(Possibly useful information: 1000 liters = 1 m³; 1 hp = 746 Watts; 1 atm = 1.01325 x 10⁵ N/m²; 1 pound = 4.448 Newtons = 4.448 kg m/s²; 1 inch = 0.0254 m; 1 hour = 3600 seconds.)

- a) BMEP
- b) friction MEP
- c) equivalence ratio
- d) brake thermal efficiency
- e) indicated torque
- f) Is this engine throttled, turbocharged or neither? Explain. (Hint: compute the volumetric efficiency.)