Mansoura University
Faculty of Engineering
Mech. Power Eng. Dept.
Third Year

Final Semester Exam
Combustion Theory- MPE 4313
January 16, 2013 - Time: 3 hours
Total Marks 90 [Exam on 2 pages]

Answer the following questions. Assume any necessary assumptions.
Use of combustion tables and air table is allowed. Mark

1. a) Discuss briefly characteristics of liquid fuels. [12]
   b) Explain major constituents of pollutants emitted by combustion systems and their effects on the environment.
   c) Using illustration, explain zones of each type of the photographing methods used for measurement of the burning velocity for a typical hydrocarbon flame.

2. Using neat illustrations, discuss each of the following: [12]
   a) Premixed combustion wave categories using Hugoniot curve.
   b) Region of stable zone of laminar premixed flames in term of velocity gradient. Also, define each of flashback and blow-off of the flame.
   c) Various regimes of premixed turbulent flames using *"Borghi diagram"*.

3. A natural gas consists of 88% methane CH_4, 8% hydrogen H_2, 4% nitrogen N_2, by volume, is burned with 10% excess air. Calculate each of; [12]
   a) The fuel-air ratio of the mixture.
   b) The volume of combustion products per unit volume of the fuel when the products are at 1.1 bar and 900 K and the fuel is at 1 bar and 310 K.
   c) The partial pressure of the water vapor in the products.

4. A stoichiometric mixture of H_2 and O_2 reacts at 1 atm and 2500 K, assume that the products (H_2O, H_2 and O_2) are in equilibrium according to the reaction; [12]

$$H_2O \Leftrightarrow H_2 + \tfrac{1}{2}O_2,$$

   Calculate the mole fractions of the products using the equilibrium constant method.

5. Derive an expression for reaction rate of NO atom using the famous Zeldovich mechanism during the formation of nitric oxide (NO), given as below: [5]

$$O + N_2 \xrightarrow{k_1} NO + N \qquad \text{(Slow)}$$

$$N + O_2 \xrightarrow{k_2} NO + O \qquad \text{(Fast)}$$

6. Determine the laminar burning velocity S_L as well as the flame thickness δ_L of a stoichiometric CH_4–air mixture considering the single step global kinetics scheme for which the average reaction rate expression is given as: [17]

$$\bar{\dot{m}}'''_F \text{ (gmol/cm}^3\text{)} = k_G \, (C_{CH4})^{-0.3} \, (C_{O2})^{2.5}$$

   [For single step global reaction, rate constant $k_G = 3.o \times 10^{14} \exp(-15000/T)$
   And take $T_F = 2200$ K and $T_u = 298$ K.]

7. A kitchen room of size 4 m x 3 m x 3 m at 0.1 MPa and 298 K is filled with propane (C_3H_8) due to leakage from propane gas cylinder of volume 0.1 m^3 initially at 0.5 MPa. Assuming that the leakage stops when the cylinder reaches 0.1 MPa, determine whether the mixture in the kitchen is flammable or not? [10]
[Note that for propane-air mixture, the stoichiometric (% fuel) = 5.6%, the lower flammability limit = 2.1% and the upper flammability limit = 9.1%].

8. A laminar butane gas (C_4H_{10}) get issued from a tube into the air has a flame height of 10 cm. Determine volumetric fuel flow rate and heat release rate. If the fuel tube diameter is increased by 25% and velocity is increased by 25%, what will be the flame height? Take heat of combustion for butane gas = 45000 kJ/kg, and $T_F = 2200$ K and $T_u = 298$ K . [The flame length h_F can be expressed as; [10]

$$h_F = \{1300\ \dot{V}_F\,(T_u\,/\,T_F)\}\ /\ ln\,(1+1/v\,)$$

where $\dot{V}_F$ is the volumetric flow rate "m^3/s" and v is the stoichiometric air fuel ratio].

Good Luck,,,, Prof. Dr. S. El-Emam