Ref. No Ex/ME/T/326G/2017

B.M.E. THIRD YEAR SECOND SEMESTER EXAMINATION, 2017
Elective-I
Combustion Engineering

Time: Three hours **Full Marks 100**

All parts of the same question must be answered together. Assume any unfurnished data suitably
Use of Thermodynamic Tables permitted
All parts of the same question must be answered together

Answer any FIVE questions

Q:1 Syngas (50% CO and 50% H_2 by volume) is burned at constant pressure in oxygen diluted with carbondioxide such that the volumetric proportion of O_2 to CO_2 is 1:3. The fuel-oxygen ratio is stoichiometric and the reactants enter the combustor at 298 K. The products leave the combustor at 1600 K. Calculate the heat transfer from the combustor. Neglect dissociation. 20

Q:2 Consider the combustion of propane in air with an equivalence ratio of 1.2. If the combusition products exit at 1800 K, what is the composition of the products if the only dissociation reaction involved is the water gas shift reaction $H_2O + CO \Leftrightarrow H_2 + CO_2$ 20

Q:3 (a) Derive an expression for the characteristic time associated with an elementary bimolecular reaction. Use the result to calculate the characteristic time associated with the reaction

$$CO+OH \rightarrow CO_2+H$$

The reaction coefficient is given by k_1 (cm^3/gmol-s) = $1.17\times10^7 T^{1.35} \exp(3000/R^*T)$ where T is the temperature in Kelvins and R^*=8.314 J/gmol-K. The temperature is T = 2000 K and mole fractions of CO and OH are 0.011 and 3.68×10^{-3} respectively. 14

(b) Consider the following reaction mechanism. Classify the elementary reactions in terms of their role in the reaction chain. Explain your answer.

$$CO+O_2 \rightarrow CO_2+O$$
$$O+H_2O \rightarrow OH+OH$$
$$CO+OH \rightarrow CO_2+H$$

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Q: 4(a) Define flame propagation speed and flame displacement speed. Explain the Bunsen burner method of determination of flame speed. Under what conditions can one obtain a conical flame? 10

(b) A cylindrical tube of diameter D is filled with fuel-air mixture. The temperature gradient near the wall can be calculated by assuming linear increase from wall temperature to burned gas temperature over a distance D/b where b is a constant. Derive an expression for the smallest diameter of the tube that can sustain flame in terms of flame thickness and b. Assume the flame to remain planar. 10

Q:5 (a) Derive the steady momentum equations in two-dimensional Cartesian form for a viscous fluid. Use these equations to derive the equation for conservation of kinetic energy. 10

(b) Derive two-dimensional steady mass conservation equation for an individual species in a chemically reacting system assuming Fick's law to be valid. Show how the mass conservation equations for individual species can be combined to obtain the overall mass conservation equation. 10

Q:6 (a) Show that under suitable assumptions, use of Shvab-Zeldovich variables can eliminate source terms from energy and species conservation equations for a reacting system. 15

(b) Sketch the configuration for Burke-Schumann flame and show the boundary conditions. 5

Q: 7 (a) Define mixture fraction. Show how local fuel and oxidizer mass fractions and temperature can be related to mixture fraction. 16

(b) In a nonpremixed flame, the fuel stream consists of methane diluted with nitrogen and the oxidizer stream consists of oxygen and nitrogen. If the fuel mass fraction in the fuel stream is 0.15 and the oxygen mass fraction in the oxidizer is 0.23, find the stoichiometric mixture fraction. 4

Q: 8 (a) Derive the expression for rate of evaporation of a single component fuel droplet in a stationary medium in terms of mass fraction of fuel vapour at the droplet surface. Use this result to derive the rate of change of droplet diameter with time. 14

(b) Derive the relation between rate coefficients of forward and backward reaction and equilibrium constant. 6