B.M.E. THIRD YEAR SECOND SEMESTER EXAMINATION, 2019
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(a) 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. 15

(b) Explain how you would calculate enthalpy of reference at high temperatures. 5

Q:2(a) Consider the combustion of methane in air with an equivalence ratio of 1.2. If the combustion products exit at 1800 K, what is the composition of the products if the only dissociation reaction involved is the water gas shift reaction $H_2O + CO \Leftrightarrow H_2 + CO_2$ 15

(b) Explain how equilibrium composition is affected by change in temperature. 5

Q:3(a) Derive the relation between kinetic coefficients of forward and backward reactions and equilibrium constant. 7

(b) Derive an expression for the chemical timescale for a bimolecular chemical reaction. 7

(c) For the following elementary reactions, mention whether they are unimolecular, bimolecular or termolecular and also explain their role in the reaction chain (chain initiating, chain terminating etc.)

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

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Q:4(a) Derive the species conservation equation in r-θ coordinate keeping the transient term. 10

(b) Derive Shvab-Zeldovich form of energy equation. Assume an energy conservation equation without pressure energy and viscous dissipation as a starting point. 10

Q:5(a) What is the requirement of a conserved scalar to analyze non-premixed flame? Define mixture fraction. 4+2

(b) The mole fractions in a methane-air flame are given for some species. The mole fractions are $X_{CH4} = 2000\ ppm$, $X_{O2} = 0.02$, $X_{CO2} = 0.01$ and $X_{H2O} = 0.15$. The balance of the mixture is nitrogen. Find out the mixture fraction and fuel-air ratio. 7

(c) Write a short note on soot in non-premixed flame 7

Q:6(a)	What do you understand as under-ventilated and over-ventilated flame?	3
(b)	What is state relationship? Show an example.	4
(c)	Show that the momentum equations are converted to ordinary differential equations for counterflow flames.	10
(d)	Why are non-premixed or partially premixed flames used in industry instead of premixed flames?	3
Q:7.(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)	Explain how blowout and flashback occur in premixed flames.	6
(c)	Show with schematic sketches the structure of a premixed flame at different length scales.	4
Q: 8	Develop a one-dimensional steady model for propagation of laminar premixed flame assuming unity Lewis number for single step reaction involving fuel, oxidizer and products. Use the above model to develop expressions for flame thickness and flame speed.	20