BE MECHANICAL. THIRD YEAR SECOND SEMESTER EXAMINATION, 2018
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

Group I
Answer any two questions

Q:1 A lean mixture of propane and air is burned adiabatically at constant pressure. The fuel-air mixture enters the combustor at 298 K while the products leave at 2800 K. Calculate the percentage of excess air in the mixture. Neglect dissociation. 15

Q:2 The products of combustion of a saturated aliphatic hydrocarbon fuel of unknown composition have 8% CO_2, 0.9% CO, 8.8% O_2 and 82.3% N_2 measured on volumetric dry air basis. Calculate the actual air-fuel ratio, composition of the fuel and the % theoretical air. 15

Q:3 Consider the combustion of methane in 25% excess air. If the reactants enter at 298.15 K and final temperature of the products is 2000 K, calculate the heat transferred from the combustor considering the dissociation of CO_2. 15

Group II
Answer any one question

Q:4(a) Derive an expression for the chemical time constant of the generic termolecular reaction $A+B+M \rightleftharpoons C+M$ where M is a third body. 9

(b) 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.)

$$CO+O_2 \rightarrow CO_2+O$$
$$H+O_2+M \rightarrow HO_2+M$$
$$HO_2+OH \rightarrow H_2O+O_2$$
$$O+H_2 \rightarrow H+OH$$
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Q:5(a) Derive the equation for conservation of mass of a reacting species for two dimensional unsteady Cartesian system. Use this equation to derive the overall mass conservation equation. 8

(b) Derive the equation for conservation of total energy for a two dimensional steady system in Cartesian coordinates. 7

Group III
Answer any three questions

Q:6 Derive an expression for quenching distance of laminar flame between two parallel plates in terms of flame speed. Both the plates are at the same temperature as the reactants. 15

Q:7.(a) Define flame displacement speed and flame propagation speed. Explain how the shape of a flame stabilized on a burner is determined by the local flow velocity and flame speed. 12

(b) What are the advantages and disadvantages of premixed flame? 3

Q: 8 Define mixture fraction. In a nonpremixed flame, the fuel stream consists of fuel diluted with nitrogen and the oxidizer stream consists of oxygen diluted with nitrogen. If the fuel mass fraction in the fuel stream is $y_{F,1}$ and the oxygen mass fraction in the oxidizer is $y_{O,2}$, find the stoichiometric mixture fraction if the stoichiometric coefficients of fuel and oxidizer are ν_F and ν_O respectively and the molecular weights of fuel and oxygen are given by M_F and M_O respectively. 15

Q: 9 Sketch the configuration of Burke-Schumann flame. Derive the governing equations for energy and species transport in terms of suitable conserved scalars, listing the underlying assumptions. What are the boundary conditions? 15

Q: 10 Derive the expression for rate of evaporation of a single component fuel droplet in a stationary medium in terms of temperature of fuel vapour at the droplet surface. Use this result to derive the rate of change of droplet diameter with time. 15

Group – IV

Q: 11 Answer **any two** parts: 10

(a) Consider combustion of a stoichiometric mixture of methane and air in a closed room. A water sprinkler spraying water droplets is used as a fire extinguisher. Set up a mathematical model to determine the final temperature and pressure in the room as a function of initial water loading (ratio of mass of water droplets sprinkled to mass of hydrogen) and initial volume fraction of hydrogen in the room. Neglect dissociation effects and assume complete evaporation of water droplets sprinkled.

(b) Combustion in a spark ignition engine can be simplified as constant volume combustion. A simple mathematical model for combustion in spark ignition engine is a two zone model, where the flame separates the combustion volume into a burned zone and unburned zone. As the combustion proceeds, the burned zone pressure and temperature increases and it expands, compressing the unburned zone ahead of the flame. Thus at any instant, the unburned zone temperature is determined by the compression (assumed isentropic) of the unburned gas by the expanding burned gas while the burned gas temperature is the constant volume adiabatic flame temperature corresponding to the unburned gas temperature. The pressure is determined by the constraint of the constant volume and is uniform across the flame and same for both the zones. Develop a mathematical model for the above problem.

(c) Consider the reaction $H_2O \leftrightarrow H_2 + \frac{1}{2}O_2$. Write down the equations needed to solve for the equilibrium concentration of hydrogen, oxygen and water. What would be the effect of pressure and temperature on the equilibrium concentration?