M.E. Power Engineering First year Second Semester Examination, 2018

Subject : Combustion Technologies **Full Marks: 100** **Time : Three hours**

Answer any five questions. Use data from Table 1 and Table 2 for calculation.

1.(a) What do you mean by quality of a reactant mixture? State and define the different parameters to express the quality of a reactant mixture. 2+4

(b) Liquid octane enters the combustion chamber of a gas turbine engine at 25°C and air enters from the compressor at 500 K. It is determined that 99% of the carbon in the fuel burns to form CO_2 and the remaining 1% burns to form CO. What amount of excess air will be required if the temperature of the gas entering the gas turbine is to be limited to 1200 K? Enthalpy of formation of liquid octane is –249952 kJ/kmol at 25°C. Neglect any heat loss from the combustor. 10

(c) Define adiabatic flame temperature and state its significance. 4

2.(a) What is dissociation in a combustion process? How does dissociation affect the peak pressure in the fuel-air cycle of a spark ignition engine and why? 2+4

(b) Show that for a constant temperature, constant pressure combustion reaction the equilibrium constant (K_p) can be expressed as,

$$K_p = exp\left(-\Delta\bar{G}_T^o/\bar{R}\,T\right)$$

where, all the terms have their standard nomenclature. 10

(c) Briefly explain the calculation method of determining the product composition of a rich hydrocarbon fuel-air mixture considering chemical equilibrium of the species. 4

3.(a) Differentiate between molecularity and order of a chemical reaction. What do you mean by a chemical mechanism? What are radicals and what is their role in the chemical mechanism? 2+2+4

(b) What do you mean by reduction of chemical mechanism? Why is it required to reduce chemical mechanism of a combustion reaction? Describe, through suitable examples, how 'steady state approximation' and 'partial equilibrium approximation' are used in reducing a chemical mechanism. 2+2+8

4.(a) What is the difference between macrostructure and microstructure of a flame? With the help of suitable plots, describe the microstructure of a one-dimensional premixed flame of hydrocarbon fuel in air. 2+6

(b) For a hydrocarbon-air mixture the peak laminar burning velocity is observed at an equivalence ratio (ϕ) slightly higher than 1, while for a hydrogen-air mixture the peak laminar burning velocity occurs near about ϕ=2. Why? 4

(c) How can the laminar burning velocity of a fuel-air mixture be measured using a Bunsen flame method? – explain. What are the limitations of this method? 6+2

5.(a) Explain the stabilization mechanism of a premixed flame on a burner using the distributions of flow velocity and flame velocity. When would you get a stable lifted flame? 8+2

(b) What are the different methods of causing ignition of a fuel-air mixture? Using the thermal ignition theory of Semenov, develop an expression of the ignition temperature in a flammable fuel-air mixture. 2+8

6.(a) What do you mean by turbulent length scales? What are the largest and the smallest length scales called? How are they related in a turbulent flow? 2+2+2

(b) Define Damkohler number, Karlovitz number and turbulent Reynolds number for a turbulent premixed flame and state their significances. On a characteristic plot show the different turbulent premixed flame regimes and discuss their differences. 6+8

7.(a) What is the significance of flame speed on the performance of a spark ignition engine? Why is high turbulent intensity required in the combustion chamber of the engine during combustion? Describe how the turbulence is achieved in the flow at the time of combustion in the engine. 3+2+5

(b) Which type of flame is a candle flame and why? Considering a candle flame to be axisymmetric, describe the microstructure of the flame using temperature distributions across the flame. How is the flame height determined from the temperature distribution? 3+5+2

8.(a) Why is atomization important in liquid fuel combustion? Differentiate between a pressure atomizer and a twin fluid atomizer. Explain which type is more suitable for gas turbine combustor application. 2+4+3

(b) Discuss the various characteristics of an atomized spray of a liquid fuel stating their importance in combustion. 6

(c) Differentiate between SMD and MMD of a fuel spray. Which of these is more relevant in combustion application and why? 5

Table: 1 – Heat of formation and Heating Values

(v: vapour, l: liquid)

Species	Enthalpy of Formation (kJ/kmol)	Higher Heating Value (kJ/kg)	Lower Heating Value (kJ/kg)
CO_2	- 393520	-	
H_2O (v)	- 241820	-	
H_2O (l)	-285830	-	
CO	- 110530	-	
CH_4	- 74850	55510	50020
C_2H_6	- 84680	51870	47480
C_3H_8	- 103850	50350	46360
C_8H_{18} (v)	- 220100	48119	44651

Table-2: $\Delta h = \left(h_T^0 - h_{298}^0\right)$ at different temperatures for species

Temperature (K)	$\Delta h = \left(h_T^0 - h_{298}^0\right)$ (kJ/kmol)				
	CO_2	CO	H_2O	O_2	N_2
298	0	0	0	0	0
500	8,301	5,943	6,947	6,097	5,920
1000	33,425	21,697	25,993	22,721	21,468
1200	44,488	28,440	34,518	29,775	28,118
1500	61,681	38,847	48,181	40,590	38,404
2000	91,420	56,737	72,805	59,169	56,130