Ref. No. : **Ex/PG/PE/T/127A/2024**

M.E. Power Engineering 1st Year 2nd Semester Examination, 2024

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

Answer any five questions.

1. a) The equivalence ratio of the fuel-air mixture inducted into the cylinder of a spark ignition engine is measured to be 0.9. Is the mixture rich or lean? What is the percentage theoretical air for the mixture? Why such mixture is used during the operation? **(5)**

   b) The fuel-air mixture prepared in the mixing tube of a domestic LPG burner has an equivalence ratio of 1.33. If the LPG (having 30% propane and 70% butane) flow rate is 60 liter/h, what is the rate of air entrained in the mixing tube? What, in your opinion, is the flame type established on the burner? – justify. **(10)**

   c) Define enthalpy of formation and discuss its significance in the thermochemical analysis of reacting flow. **(5)**

2. a) Define adiabatic flame temperature and discuss its significance in practical applications. **(6)**

   b) A natural gas containing 80% methane and 20% ethane by volume is burned in a reactor with 150% theoretical air in a steady state steady flow process. Heat is transferred from the reactor for process purpose and the products of combustion leave the reactor at 1000 K. The fuel enters the chamber at 25°C and the air supply is preheated to 500 K. Write down the global reaction equation and determine the heat transfer from the reactor per kg of the fuel supplied. The reactor operates at atmospheric pressure. **(14)**

3. a) How does higher heating value of a fuel differ from its lower heating value? For which fuels these two values can be equal? **(3+2)**

   b) What is dissociation in a combustion process? How does it affect equilibrium in the combustion product?

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

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

   where, all the terms have their standard nomenclature. **(3+2+10)**

4. What do you mean by a chemical reaction mechanism? What are the individual reactions of the mechanism known as? What is the molecularity of these reactions? How is the specific reaction rate of these reactions expressed? **(2+1+2+2)**

   b) What are the differences between a global reaction mechanism and a reduced reaction mechanism? Explain any one method of reduction of a chemical reaction mechanism with suitable example. **(3+5)**

   c) What do you mean by a well stirred reactor? Under which condition a reactor can be modeled as well stirred reactor in practice? **(3+2)**

5. a) Define laminar burning velocity of a premixed flame. Explain the influence of various factors on the laminar burning velocity of a premixed fuel-air mixture. **(2+6)**

   (b) Derive an expression of burning velocity of a laminar premixed flame using a simplified analysis of one-dimensional and steady flame. Clearly state the assumptions considered for the derivation. **(12)**

[Turn over

6. a) What do you mean by flash back and blow off of an open premixed flame? Explain the structure and stabilization principles of open flames, established on a circular burner, burning a premixed fuel-air mixture. **(12)**

b) Derive an expression of critical kernel radius for spark ignition of a premixed reactant mixture in terms of laminar flame thickness. **(8)**

7. a) What is flammability range of a fuel-air mixture? Why is it not possible to establish a premixed flame outside the flammability range of fuel-air mixture in an enclosure? **(3+5)**

b) What is a partially premixed flame? How does its structure differ from the structure of a premixed flame? **(3+5)**

c) Explain why the premixed flames of different fuels emit different colours. **(4)**

Table: 1 – Heat of formation and Heating Values

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}	- 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