Final examination for Introduction to Combustion

Time allowed: Two hours

Fall semester, 2018-2019

Answer ALL questions

Total mark: 100

Any hardcopy material can be used, but no electronic devices except for non-programmable calculator is allowed.

Molar mass may be needed:

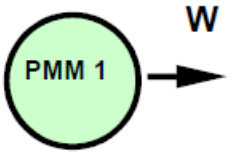
$$M_O = 16\ kg/kmol,\ M_H = 1\ kg/kmol,\ M_C = 12\ kg/kmol,$$
$$M_N = 14\ kg/kmol,\ M_{air} = 28.85\ kg/kmol$$

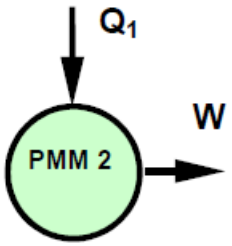
Air is considered 21% of O_2 and 79% of N_2.

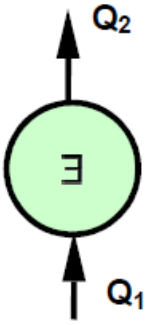
1. Multiple choice questions. Select ONE answer for each of the following questions. Each question carries **4** marks.

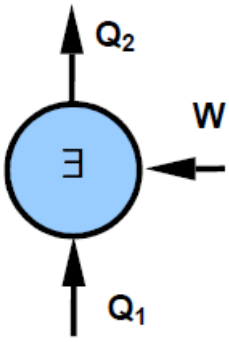
1) Which one of the following quantities is NOT a property?
   A. Heat
   B. Specific volume
   C. Density
   D. Internal energy

2) Which one of the processes is POSSIBLE from a thermodynamic point of view?

A. 

B. 

C. 

D. 

3) Which one of the following statements is INCORRECT?
   A. The Standard Reference State is defined as Temperature $T_{ref} = 0$℃, Pressure $p^0 = 1\ atm.$
   B. Standardised enthalpy at temperature T is the sum of enthalpy of formation and the sensible enthalpy change from T_{ref} to T.
   C. For the elements in their naturally occurring state, such as O_2, their enthalpies of formation are zero.
   D. The enthalpy of formation is only decided by the reactants and products, independent of the process.

4) In the following elementary reactions, which is likely the slowest one?
   A. $N_2 + O \rightarrow NO + N$
   B. $CO + OH \rightarrow CO_2 + H$
   C. $CH + N_2 \rightarrow HCN + N$
   D. $H + OH + M \rightarrow H_2O + M$

5) Which one of the following statements about laminar premixed flame is INCORRECT?
   A. For most of the fuels, the flame speeds are at their maximum values at a slight rich mixture.

B. Laminar flame speed has a strong temperature dependence.
C. The maximum flame thickness usually occurs near stoichiometric fuel/air mixture.
D. With addition of inert gas, flame velocity will reduce.

(Total marks: 20)

2. Complete the figures using the given items.

1) Figure 2.1 indicates a typical premixed combustion flame. Fill A to E with the given items (Reactants χ_R, Temperature T, Heat release rate $\dot{Q}'''$, Preheat zone, Reaction zone)

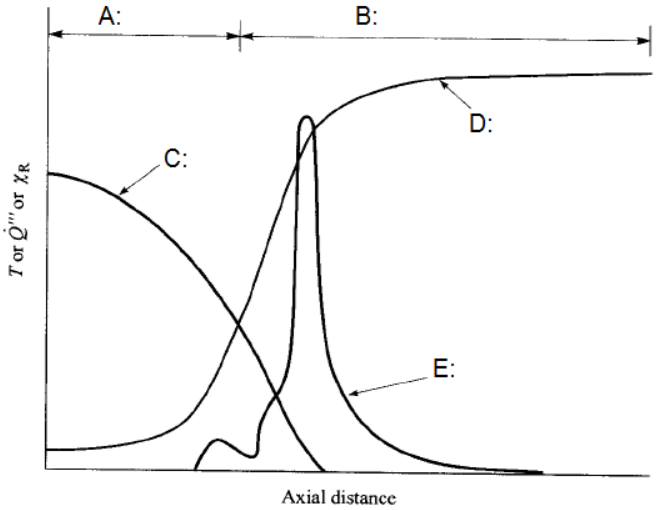


Figure 2.1

(15 Marks)

2) Figure 2.2 indicates a jet flame. Fill the A to E with given items (Flame zone, Fuel fraction, Oxidiser fraction, Flame length, Rich zone)

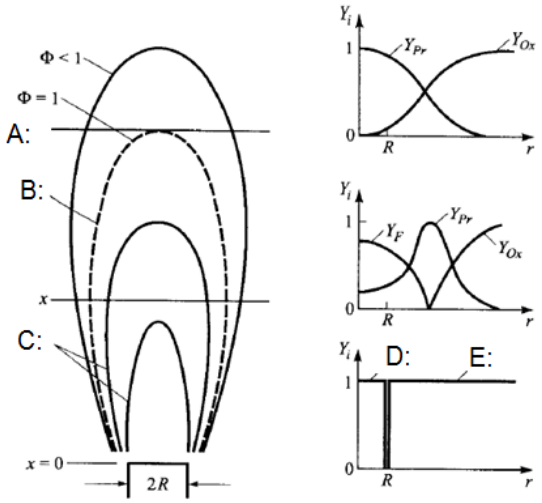


Figure 2.2

(15 Marks)

3. Calculation.

1) A typical house brick wall is constructed of two layers of bricks and a foam insulation layer between the brick layers. The conductivity of the brick is k = 1 W/m.K and the conductivity of the foam is k = 0.035 W/m.K. The thickness of the two brick layers is the same at 0.1 m, and the foam insulation is 0.2 m thick. The inner air temperature

is 20°C and the heat transfer coefficient is 9 W/m^2.K. The outer temperature is 5°C and the heat transfer coefficient is 20 W/m^2.K.

Draw a thermal resistance network. Determine the heat losses through a wall of 3 meters high and 5 meters long.

(16 Marks)

2) Calculate the stoichiometric A/F ratio of ethane (C_2H_6). Estimate the constant pressure adiabatic flame temperature for the combustion of a stoichiometric C_2H_6-air mixture at 1 atm and the initial temperature of 298 K. Use the constant specific heat at 1200 K for your calculation.

(16 Marks)

3) Liquid isopentane (C_5H_{12}) is contained in a 2-cm-diameter glass tube at 20℃ and maintained at a level 0.2 m below the top of the tube. Its corresponding saturation pressure at this temperature is 79 kPa. The molar mass of isopentane is $M_{C_5H_{12}} = 72\ kg/kmol, D_{C_5H_{12}-air} = 8.3 \times 10^{-5}\ m^2/s$. Calculate the mass evaporation rate (kg/s) of isopentane and the time takes to evaporate 1 gram of isopentane.

(18 Marks)

Bonus question:

For the following reaction mechanism,

$$H + O_2 \Leftrightarrow OH + O \quad \text{R.1}$$
$$O + H_2 \Leftrightarrow OH + H \quad \text{R.2}$$
$$OH + H_2 \Leftrightarrow H_2O + H \quad \text{R.3}$$
$$O + H_2O \Leftrightarrow OH + OH \quad \text{R.4}$$
$$H + H + M \Leftrightarrow H_2 + M \quad \text{R.5}$$

Define j and I as

j	Species	i	Reaction
1	O_2	**1**	R.1
2	H_2	**2**	R.2
3	H_2O	**3**	R.3
4	O	**4**	R.4
5	H	**5**	R.5
6	OH		
7	M		

Using j as the column index and I the row index, write the stoichiometric coefficient matrices ν'_{ji} and ν''_{ji} for the form of $\sum_{j=1}^{7} \nu'_{ji} X_j \Leftrightarrow \sum_{j=1}^{7} \nu''_{ji} X_j$ for $i = 1, 2, 3, .., 5$

(10 Marks)