

## MASTER OF MECHANICAL ENGINEERING EXAMINATION, 2017

(Second Semester)

## Combustion Engineering

Time: Three hours

Full Marks: 100

*Answer any four questions. All parts of the same question must be answered together. Use of tables permitted. Assume any unfurnished data suitably.*

- 1a) 40% Propane and 60% Butane by volume are mixed to form a fuel. Find out the stoichiometric fuel-air ratio for the fuel 5
- b) Estimate the constant pressure adiabatic flame temperature for the combustion of a stoichiometric methane-air mixture. The pressure is 1 atm and initial temperature is 298 K. Assume complete combustion of methane (product contains CO<sub>2</sub>, H<sub>2</sub>O and N<sub>2</sub> only). Assume enthalpies of formation [kJ/kmol] at 298K as CH<sub>4</sub>: -74831, CO<sub>2</sub>: -393546, H<sub>2</sub>O: -241845, N<sub>2</sub>: 0. Assume average specific heats [kJ/kmol K] as CO<sub>2</sub>: 56.21, H<sub>2</sub>O: 43.87, N<sub>2</sub>: 33.71. 5
- c) Starting from equilibrium thermodynamic relation  $(dG)_{T,P,m} = 0$ , show that  $K_p = \exp(-\Delta G_f^0 / R_f T)$  15
- 2a) Find out the expression for  $dT/dt$ ,  $dP/dt$  and  $d[X_i]/dt$  for a constant volume reactor. Also comment on the boundary conditions to solve for the above variables. The variables bear their usual meaning. 20
- b) Write a short note on activation energy. 5
- 3a) Derive the expression for laminar flame speed in a uniform fuel-oxygen mixture assuming a cubic temperature profile in flame. 20
- b) A premixed fuel-oxidizer mixture is coming out of a slot burner with a velocity  $u = U(1 - x^2/L^2)$  5  
Where, U is the maximum velocity, the slot width is 2L with x=0 at the centre. Find out an expression for flame shape for this burner.
- 4a) Derive the transient species conservation equation for an axisymmetric system. Modify the equation for a system where radial velocity is negligible compared to axial velocity and diffusion is in radial direction only. 12+3
- b) Derive the Shvab-Zeldovich form of energy equation. 10
- 5a) Derive the expression for mixture fraction on a slot burner assuming Burke-Schumann flame. 20
- b) Find out the stoichiometric mixture fraction Methane (CH<sub>4</sub>) diluted with 20% Nitrogen by mass and air. 5
- 6a) Write a short note on flame quenching. 5
- b) Derive the expression for mixture fraction and the transient conservation equation of mixture fraction from the above modified equation. 4+6
- c) Write a short note on soot generation in non-premixed flame. 10