Q2 A fire is created in a room. The height of the door is 1.83 m and its width is 0.74 m. The neutral plane is established at the height 1.0 m. The fire is sustained by propane (C_3H_8) with a mass flow rate of $\dot{m} = 1.25 \cdot 10^{-3}$ kg/s and the oxidiser is air (79% vol. nitrogen N_2, 21% vol. oxygen O_2). The air flows through the door opening with an average velocity of V_{in}=0.7 m/s and a temperature of T_{in}=298K.

(i) Write down equation for stoichiometric propane-air reaction; calculate the stoichiometric ratio for propane combustion in air. (3 marks)

(ii) Calculate the lower heat of reaction for propane on a molar and a mass basis (i.e. per 1 mole and per 1 kg of propane). (7 marks)

Use following heats of formation:

Substance	Heat of formation, h_f^0, J/mol
C_3H_8 (gas)	-103,800
O_2 (gas)	0
CO_2 (gas)	-393,500
H_2O (gas)	-241,800
N_2 (gas)	0

(iii) Calculate the adiabatic flame temperature for propane combustion in air. (7 marks)

Use following specific heats of species at T=1600K:

Substance	Specific heat, c_p, J/mol/K
CO_2 (gas)	58.9
H_2O (gas)	32.7
N_2 (gas)	35.1

(iv) Determine the average temperature and velocity of outflowing gases. (8 marks)

Apply the principle of energy conservation for a steady-state open system. Neglect the difference in kinetic and potential energy of inflowing and outflowing gases as compared to the rate of energy transfer to the gases (i.e. due to the heat release rate by the fire). Assume that

- the combustion is perfect,
- the entire heat of reaction is spent on heating of gases in the room;
- the average specific heat of outflowing gases is c_p=1050 J/kg/K and the average molecular mass of the outflowing gases is equal to that of the ambient air M_{in}=M_{out}=29 kg/kmol.