Combustion in Air-breathing Aero Engines
Assignment No. 6

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This assignment contains 8 multiple choice questions with 4 possible answers to each. Only one of the choice is correct and so select the choice that best answers the question. Correct choice rewards you with 1 point for each question. Wrong answers will reward you with 0 points (no negative marking). The questionnaire contains both numerical and concept-based questions. All the best!!!

Q1: For the Frank-Kamenetskii solution of a premixed laminar flame, which of the following conditions hold

(a) reactions in the pre-heat zone are ignored

(b) reactions in the pre-heat zone are not ignored

(c) $(f^o)^2 \sim \frac{1}{Ze}$

(d) $(f^o)^2 \sim \frac{1}{Ze^2}$

Choose the correct answers from the following choices:

1. a only
2. a. & d. only
3. b only
4. b. & c. only

Ans: The correct choice is 2.

Q2: In stagnation flame method, the flame speed

1. is laminar and flame is not stretched
2. is laminar and flame is stretched
3. is not possible to measure
4. is zero because the flame is stationary

Ans: The correct choice is 2.

Q3: The following is an assertion and reason question. Choose your option that best matches with the situation in the table:
Assertion: Flame speed of $C_2H_6 < C_2H_4 < C_2H_2$
Reason: The adiabatic flame temperature for $C_2H_6 < C_2H_4 < C_2H_2$
Ans: Both the assertion and reason are individually correct statements. However, the reason is not the complete explanation for the assertion. When the laminar flame speeds C_2H_4 and C_2H_2 is evaluated with N_2 dilution to such an extent that the adiabatic flame temperature of the respective stoichiometric mixture matches that of the C_2H_6-air mixture, the laminar flame speed still increase in the order shown above demonstrating the influence of the molecular structure of the fuel. Therefore, the correct choice is 2.

Choice	Assertion	Reason	Remark
1.	True	True	Explanation is correct
b.	True	True	Explanation is incorrect
c.	False	True	
d.	False	False	

Table 1

Choice	Assertion	Reason	Remark
1.	True	True	Explanation is correct
b.	True	True	Explanation is incorrect
c.	False	True	
d.	False	False	

Table 2

Q4: The following is an assertion and reason question. Choose your option that best matches with the situation in the table 2
Assertion: HO_2 production peaks upstream in a H_2-air flame releasing significant heat in the pre-heat zone
Reason: H radical has high diffusivity and back diffuses upstream
Ans: The assertion is true because HO_2 production is maximum in upstream region of the flame. The heat release for a laminar H_2 air flame peaks at around 800K. The reason is also correct. However, it does not completely explain the assertion. The activation energy for termination reaction $H + O_2 + M \rightarrow HO_2 + M$ is also zero which favors the reaction at low temperatures. Therefore, the correct choice is 2.

Q5: Assuming u_u is the upstream fluid speed and α_u is the angle of the flame with the vertical, for a Bunsen flame, the local laminar flame speed S_L is given by:

1. $S_L = u_u \sin \alpha_u$
2. $S_L = u_u \cos \alpha_u$
3. $S_L = u_u / \sin \alpha_u$
4. $S_L = u_u / \cos \alpha_u$

Ans: For a Bunsen flame, $S_L = u_u \sin \alpha_u$. Therefore, the correct choice is 1.

Q6: For which of the following conditions the S-curve is folded:

(a) High activation energy

(b) Low initial temperature

(c) Low activation energy

(d) High initial temperature

Select the choice that best answers your choices

1. a. and b.
2. b. and c.
3. c. and d.
4. b. and d.

Ans: The correct choice is 1.

Q7: Consider the following statements:
Statement # 1: Ignition will only occur if energy is added to the gas to heat a slab as thick as a steadily propagating laminar flame to the adiabatic flame temperature
Statement # 2: The rate of liberation of heat by chemical reactions inside the slab must approximately balance the rate of heat loss from the slab by thermal conduction
Select the correct option from below:

1. Statement 1 is appropriate for ignition; statement 2 does not hold
2. Statement 1 does not hold; statement 2 is appropriate for flame extinction
3. Statement 1 is appropriate for ignition; statement 2 is appropriate for flame extinction
4. Both statement 1 and 2 do not hold

Ans: The correct choice is 3.

Q8: Consider a flame in a slot formed by two plane-parallel plates. Let T_b and T_w denote the burnt gas temperature and the temperature at the wall. Assume that the temperature gradient from the center to the wall can be approximated by a linear function. λ is the thermal conductivity of the mixture, $\dot{w}$ is the average reaction rate per unit volume and Δh_c is the heat of combustion of fuel. Estimate the quenching distance d, using a suitable quenching criteria.

1. $k\frac{(T_b-T_w)}{\dot{w}\Delta h_c}$
2. $2k\frac{(T_b-T_w)}{\dot{w}\Delta h_c}$
3. $\left[k\frac{(T_b-T_w)}{\dot{w}\Delta h_c}\right]^{1/2}$
4. $\left[2k\frac{(T_b-T_w)}{\dot{w}\Delta h_c}\right]^{1/2}$

Ans: To evaluate the quenching distance, we use statement 2 from the previous question. In simple form,

$$\text{Heat liberated from chemical reactions} = \text{Heat conducted to the walls}$$

Assume that the flame is δ units thick and the depth of the slot is L. These assumptions are not going to affect the final solution. Therefore,

$$\dot{w}\Delta h_c\,(Ld\delta) \quad = \quad k\,(L\delta)\,\frac{dT}{dx}$$

Since, the temperature gradient is to be approximated using a linear function $dT/dx = (T_b - T_w)\,/\,(d/2)$.

$$\begin{aligned}
\dot{w}\Delta h_c d &= k\frac{(T_b - T_w)}{(d/2)} \\
d^2 &= 2k\frac{(T_b - T_w)}{\dot{w}\Delta h_c}
\end{aligned}$$

Thus, the correct answer is 4.