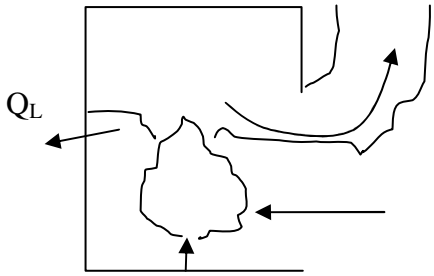
ME 382R, Fire Dynamics
Exam 1 Example Questions

Typically two questions on an Exam.

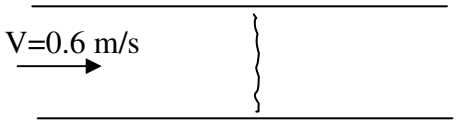
1. Methane is supplied to a burner in a room for an experiment at 20 g/s. The measurements indicate that airflow into the room doorway is 800 g/s and the door is the only opening. Heat loss through the walls of the room is estimated to be 200 kW. The exhaust leaves the room through the upper part of the doorway at a uniform temperature. Assume that the methane burns completely to CO_2 and H_2O.

a) Calculate the temperature of the exhaust gases. (20 pts)
b) Calculate the mass flow rate of O_2 in the exhaust stream. (15 pts)
c) Calculate the mass flow rate of O_2 entering the room. (5 pts)
d) Calculate the difference between the (c) and (b) and multiply this number by the heat of combustion on an oxygen basis. (10 pts)
e) Compare and discuss the heat release rate (kW) calculated by (d) with that calculated on a fuel basis. (10 pts)

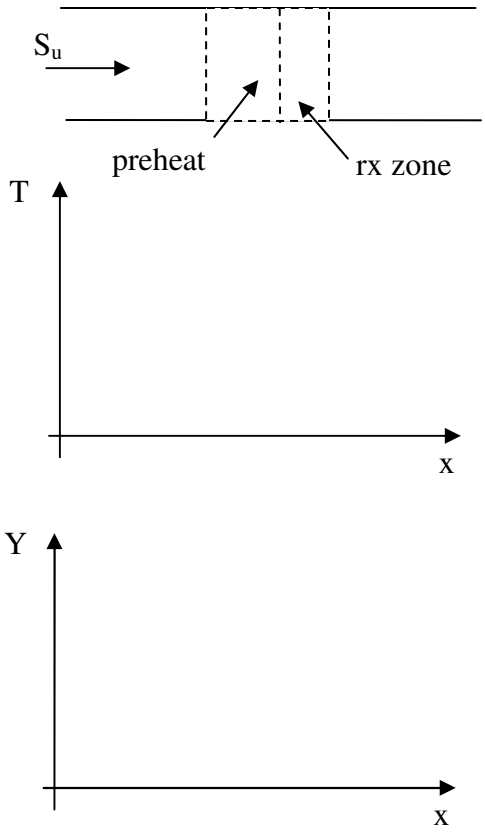


2. Question 2 is a series of short answer questions.
a) A heating fuel is a mixture of methane (30%) and propane (70%). What is the LFL (mole fraction) of the mixture in air? (15 pts)

b) A premixed flame with a laminar flame speed of 0.4 m/s propagates in a channel. The flow of reactants is 0.6 m/s. Find the flame velocity (in lab coordinates) and show by an arrow the direction in which the flame is observed to move. (10 pts)



c) An adiabatic stationary premixed flame is shown below (within dashed CV). Sketch the temperature profile on the axis immediately below the flame schematic. Sketch the fuel mass fraction, oxygen mass fraction, and nitrogen mass fraction on the next set of axes. (15 pts).



1. These are short answer questions on flames. Specify units to receive full credit.

a. What is a reasonable engineering estimate for the, laminar flame speed for a stoichiometric mixture of a simple hydrocarbon like methane?

b. Approximately how thick is the flame thickness (preheat zone thickness) for a premixed methane-air flame?

c. In a laboratory frame of reference, an observer measures the velocity of burned gases (V_b), the premixed flame front (V_f), and the unburned gases (V_u). What simple relationship relates the laminar flame speed (S_u) to these measured velocities?

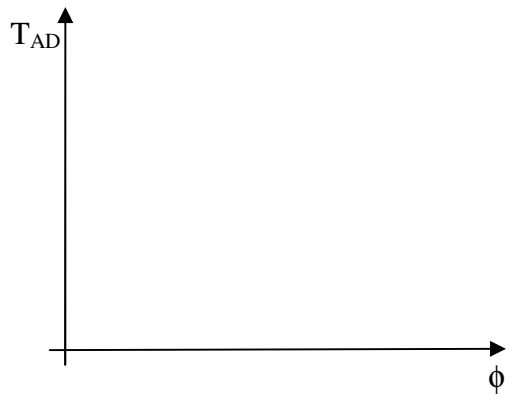
d. Approximately, what is the adiabatic flame temperature a stoichiometric methane-air flame?

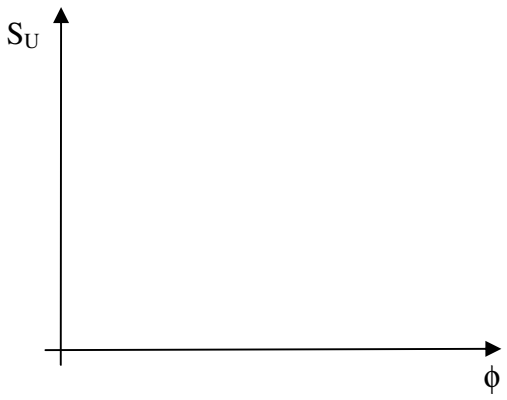
e. The lean flammability limit can be computed by considering a mixture strength that would allow the adiabatic flame temperature to reach a critical value. What is a reasonable engineering estimate for this critical temperature?

f. It is often useful to compute flame temperatures and heat release rates using the heat of combustion on an oxygen basis. What is a reasonable engineering estimate for the heat of combustion on an oxygen basis?

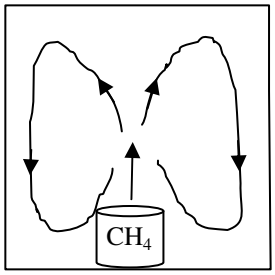
g. Sketch the adiabatic flame temperature (T_{AD}) dependence on equivalence ratio (ϕ).

h. Sketch the laminar flame speed (S_u) dependence on equivalence ratio (ϕ).





1. A near empty methane tank stored in a structure develops a small leak at time t=0. The tank initially contained 4 kg of methane. The structure has a volume of 30 m^3 and is well sealed. The initial structure pressure is one atmosphere. The temperature in the structure remains at 25C throughout the filling process. The leakage rate of the methane from the tank into the structure is constant at 2 g/s. Assume that the leaked methane is always well mixed in the structure volume. Answer the following questions about this scenario. State any simplifying assumptions that you use. Provide a check as necessary on the appropriateness of the assumption.



   a) At what time after the methane leak starts is the mixture in the structure flammable?

   b) At what time after the methane leak starts does the mixture transition from flammable to not flammable?

For parts c & d assume that the mass of methane contained in the tank has completely leaked out into the structure.

   c) What is the mass fraction of methane in the structure after the tank has emptied?

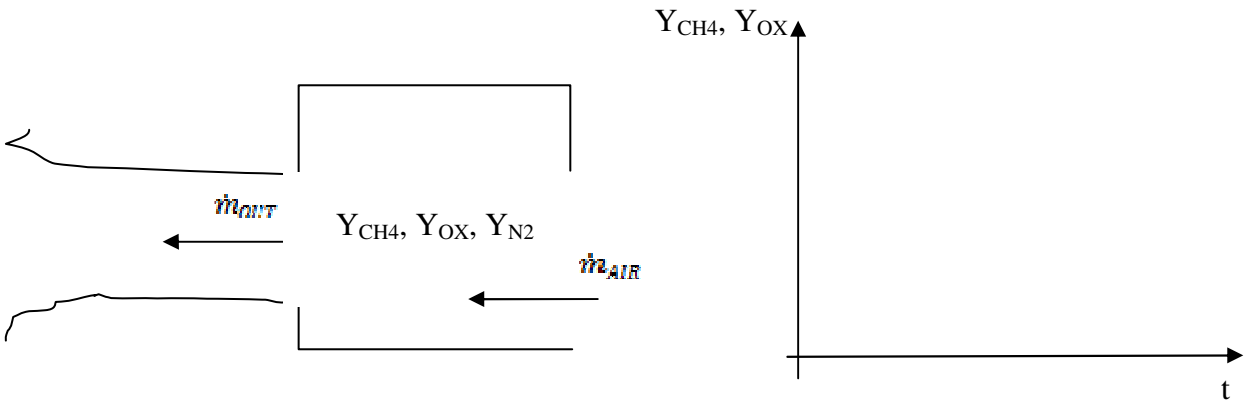
   d) What is the mass fraction of oxygen in the structure after the tank has emptied?

2. To clear a structure filled with a mixture of methane and air, a fan is placed at the front door of the structure and a window is opened on a different side of the structure. The fan blows air into the structure at 1 kg/s. Assume that the total mass of gas in the structure is constant and is 40 kg. Also assume that the initial mass fraction of methane (Y_{CH4}) is 0.15 and the remaining gas is air.

   a) Specify the conservation law in an appropriate form that describes how the methane mass fraction changes with time in the structure as a result of the fan blowing air into the structure. Remember that the air flowing into the structure is assumed to instantaneously mix with the gases already in the structure.

   b) What is the initial mass fraction of oxygen?

   c) Sketch the exiting methane and oxygen mass fractions as a function of time.



   d) Is the initial mixture in the structure flammable? If not, how much more methane would have been required to make the mixture flammable? If so, over what time range after the fan has been turned on is the exiting mixture flammable?

   e) If you were to compute the difference in the mass flow rate of oxygen into and out of the structure, would this be zero, positive, or negative?

   f) Discuss the appropriateness of identifying the heat release rate with the difference in oxygen flow rates for a problem like this.