1. Using GRI mechanism, and the accompanying thermo and transport file, compute the structure and flame speeds of 1D planar steady adiabatic laminar premixed flame:

   (a) Compute the flame speeds of CH_4/air mixtures at different equivalence ratios at an unburnt temperature of $T_u = 298$ K and pressure of 1 atm for $\phi = 0.6$–1.4 at steps of 0.1. Plot the maximum flame temperature and S_u^0 vs ϕ.

   (b) Take a look at grid point distribution used in the solution file. From a plot of temperature vs y, find out how many grid points are located on the flame.

   (c) Determine how lean a mixture you can still obtain a converged burning solution, by decreasing ϕ from 0.6. Similarly, determine how rich a mixture you can still obtain a converged burning solution, by increasing ϕ from 1.4. These are the lean and rich flammability limits, respectively.

   (d) Are the flammability limits the same if radiation is turned off?

   (e) Plot major species – $CH_4, O_2, CO, CO_2, H_2O$ across the flame. Similarly, plot minor species – for instance, $H_2, CH_2O, C_2H_4, C_2H_6$ along the flame, and radicals – for instance, CH, HCO, OH, H.

   (f) Repeat the calculation in (a) for pressures $p = 10, 100$ atm. Plot the maximum flame temperature and S_u^0 vs ϕ at different pressures. Comment on how the value of ϕ at which maximum S_u^0 is achieved changes as pressure increases. Can you explain this trend?

   (g) Repeat the calculation in (a) for unburnt temperatures $T_u = 500$ K. Plot S_u^0 vs ϕ at different unburnt temperatures, $T_u = 298$ K (from part (a)), 500 K.

2. Using GRI mechanism, and the accompanying thermo and transport file, compute the structure of counterflow non-premixed flame of methane.

   Consider the case of fuel and oxidizer nozzles separated infinitely away (stagnation point flow), where the controlling parameter is the flow strain rate, a. Take the fuel side to be entirely methane, $Y_{F,1} = 1$. Assume the oxidizer side to be air. Let the temperatures of the fuel and oxidizer side be set at 298 K and the pressure $p = 1$ atm.

   Part I:

   (a) Compute the solution for $a = 100s^{-1}$

   (b) Take a look at grid point distribution used in the solution file. From a plot of temperature vs y, report the number of grid points located on the flame versus the total number of grid points used in the domain.

   (c) Plot temperature, major species – $CH_4, O_2, CO, CO_2, H_2O$ across the flame. Similarly, plot minor species – for instance, $H_2, CH_2O, C_2H_4, C_2H_6$ across the flame, and radicals – for instance, CH, OH, H.

   Part II:

   (a) Compute the solutions for a range of strain rates, $a = 100, 200, 300, 400, 500s^{-1}$.

   (b) Plot the maximum flame temperature vs a. Explain the observed trend.

   (c) Plot the flame extent versus a. Explain the observed trend.

   (d) The strain rate a_q at which the flame is no more present is called the extinction strain rate. Report a_q for the above case.

   (e) Repeat the calculation in (d) for $p = 10$ atm. How different are the results in a_q? Can this be explained? Comment on the resistance of non-premixed flames to extinction as pressure is increased.

   (f) Repeat the calculation in (d) for $Y_{F,1} = 0.5$ and rest N_2 on the fuel side. How different are the results in a_q? Can this be explained? Comment on the resistance of non-premixed flames to extinction upon dilution.