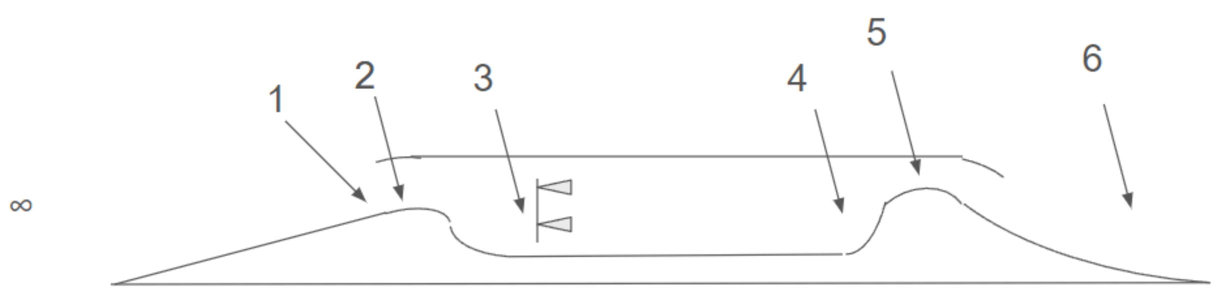
Final Project
Due 5/10/2024

General Instructions:

- For all HW and the course in general it is imperative that you remain cognizant of the limits of models and assumptions. As such, points will be deducted for not listing out any assumptions that aren't inherent in the phrasing of the problem that you then rely on to form an answer. There will be some leniency given in the first homeworks but will become more strict as the course progresses.
- Show your work or code as applicable, partial credit will be given for thought process even if implementation falters. Answers with no work will not receive credit.
- If necessary cite sources you need to complete work. Wikipedia is a fine place to start a search, but not end. Always read and cite the source.

1. Design a Ramjet engine, capable of producing some net positive thrust and then analyze its theoretical performance in the range of Mach numbers between 2.75 and 3.25. For all cases assume the vehicle is flying at 55,000 ft. The engine will consist of a number of components:

    a. Inlet Section, to be composed of a finite number of oblique shocks. The resulting geometry and shock structure should be such that all flow going into the Diffusion section is of uniform properties. Assume that as the last step of the inlet there is a terminating normal shock which takes the flow from supersonic to subsonic and generates the conditions going into the Diffuser section. (inf to 2)
    b. Diffuser Section, to be treated as a quasi 1D isentropic flow (2 to 3)
    c. Flameholder Section, to be modeled as described below (3 to 3')
    d. Combustor Section, to be treated as 1D flow with heat addition (3' to 4)
    e. Converging Section, to be treated as quasi 1D isentropic flow (4 to 5)
    f. Nozzle Section, to be designed using the method of characteristics for steady 2D flow. (5 to 6)



Assume:

- Your fuel is H_2 with a lower heating value of 120 MJ/kg
- The introduction of fuel only contributes heat to the bulk flow, the additional mass and associated changes with it can be neglected
- CPG throughout
- Gamma = 1.4 throughout
- External flow is taken to be inviscid but pressure drag from differing entrance and exit areas will still be applicable per the design of flow structures necessary to close out the design.
- Flameholder to be modeled as adiabatic flow with a pressure drop across the region as defined by:
  - $\Delta P/P = 0.81\,\gamma M^2$
- Combustor: Fuel takes time to burn, a very simplified model can be expressed as
  - $\tau = 325p^{-1.6} exp(-\ 0.8 * T_0/1000)$
  - Where P is in atm, T is in Kelvin, and tau is in microseconds
  - For your designed combustor, calculate all properties as if all fuel is burnt instantaneously, then estimate whether all the fuel indeed did burn in the combustor. Do so by assuming that the velocity within the combustor can be approximated as the average of the exit and entrance velocities. This should theoretically then give you a length requirement for your combustor.

Deliverables:

1. Presentation (To be presented on 5/10/2024 in class), approximately 20-30 mins (roughly 20-30 slides)
2. Report (To be turned in on 5/10/2024) including code used to generate results

Both are to cover the following topics:

   a. Team Name and Engine Name
   b. Overall 2D profile of Ramjet
   c. Analysis methodology of each subsection
   d. Final design of each section
   e. Distribution of key parameters as a function of axial length x, from the tip of the first compression surface of the inlet to the tip of the nozzle exit: pressure, temperature, stagnation pressure, stagnation temperature, relative entropy change from free stream flow,
   f. Comparison of design operating at different Mach numbers, this includes thrust accounting, and design fuel flow rate to achieve said thrust.

3. All team members are responsible for understanding all points of analysis and design choices and decisions. This will be inquired upon.

Teams:

- Akil, Calder, Scott, JP
- Matthew, Kevin, Jacob
- Kushant, Christos, Angel
- Jack, Harry, Evan