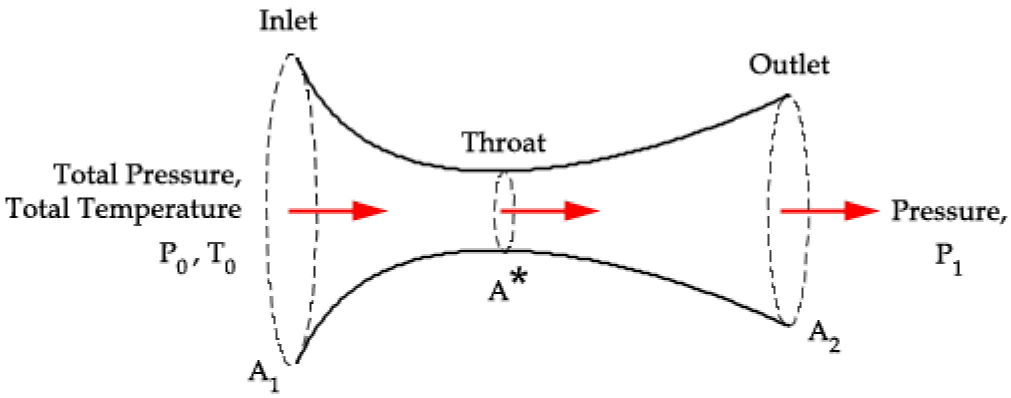
COMP208: Computers in Engineering

Winter 2016

Assignment 5

Flow through a converging/diverging nozzle



Due Date

Assignment 5 is due on Tuesday, April 4 at 23:59. The cutoff is automated and is exactly at this time. Assignments submitted within the next hour will be considered late. After that time they will not be accepted at all. The assignment is to be done individually. You can collaborate on understanding the problem but you must write the solutions independently. Submissions might be subject to being checked by plagiarism detection software.

Introduction - Critical Area & Mach Number

In this assignment you will be tasked to find the Mach Numbers related to a given critical area ratio. The critical area ratio is a given area A over the critical area A* for any given flow. A* is the minimum area in which Mach 1 is achieved with maximum mass flow rate dm/dt in [kg/s]. This characteristic A* combined with the Temperature and Pressure constants at flow stagnation is what gives rise to the critical area ratio versus Mach number function.

The function is given as follows:

$$\frac{A}{A*} = \frac{1}{M}\left[\frac{2}{\gamma+1}\left[1+\frac{\gamma-1}{2}M^2\right]\right]^{\frac{\gamma+1}{2(\gamma-1)}}$$

- A is cross sectional area of flow
- A* is critical area for Mach 1 and maximum mass flow rate

- M is Mach number
- γ is the specific heat ratio Cp/Cv for air, nominally $\gamma = 1.4$

The area ratio function is a very important function as it relates the change in area for a given shaped nozzle with the properties of an ideal isentropic air flow. It allows the aerodynamicist to determine the given Mach number of a compressible fluid flow as it passes through a converging/diverging nozzle. This relation only works for a nozzle with gently changing cross sectional area in order for flow to be considered isentropic. Thus, with known geometrical units, we can determine the speed of flow at any point. Unfortunately, since the function is a higher order function it is hard to analytically find the M roots associated with a given ratio. This is where we apply root finding numerical methods to solve for M. An interesting aspect of the function is that for a given ratio, you will find two Mach numbers which are respectively subsonic and supersonic states for the flow. This means that the flow has two choices, either to stay subsonic while passing the throat or pursue supersonic state. This is beyond the scope of this exercise but, to give you an idea, the M-state is a property of pressure gradient. The pressure gradient determines the transition and it depends on pressure ratio P*/Po=0.5283. This means for subsonic to supersonic transition, P* must be about half of Po.

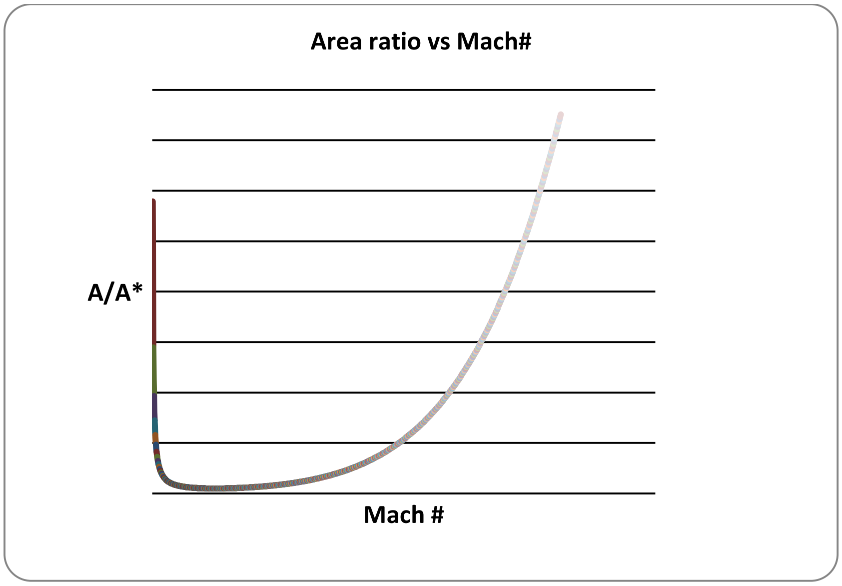
Tasks:

- In order to better understand the function. You are first to output the values of A/A* in a chart with Mach numbers ranging from 0.01 to 6.5. This can be done using a spreadsheet charting function that is available in spreadsheet applications such as Excel

- You then need to create a root finding algorithm which will determine the associated Mach numbers related to a user given A/A* ratio.

  [hint] The graph helps you compare your root findings with the actual curve to see if it makes sense. The derivative of A/A* is zero at M=1 ***

The graph should look like this:



The output should look like this:

A/A*= …

Msubsonic=…

Msupersonic=…

Here are some reference values to help you along:

A/A*	M subsonic	M sonic
1.7	0.369	2.009
2	0.306	2.197

Requirements

- The programs must be written in C
- Use meaningful variable names
- Comment and indent your code. It is your responsibility to make it readable to the grader.
- Submit both the source file (.c), excel chart, and name your file A5_123456789 where1234567898 is replaced by your student ID number.