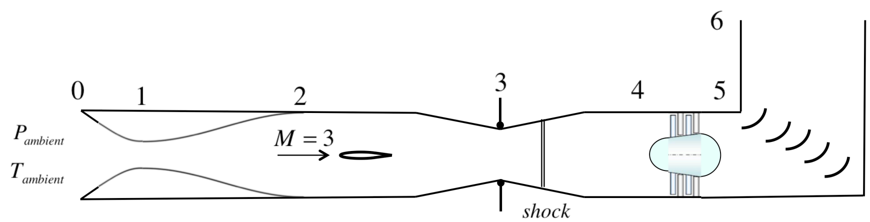
AA210A Homework 9, 2020 - 2021

Due Thursday November 19

Read Chapters 13 and 14

Chapter 13 - Problem 8

Problem 1 – The figure below shows an indraft supersonic wind tunnel similar to the one used in the fluid mechanics film "Channel Flow of a Compressible Fluid". The ambient temperature and pressure of the air drawn into the tunnel are $T_{ambient} = 300K$ and $P_{ambient} = 10^5 N/m^2$. The geometry of the tunnel is fixed except for station 3 where a pair of mechanical jacks are used to vary the throat area at this station. The area ratio of the upstream throat is $A_2/A_1 = 4.2346$ so as to achieve a test section supersonic Mach number, $M = 3$. Areas are, $A_0 = A_2 = A_4 = A_5$ and $A_6 > A_5$. The mass flow rate is $5kg/\sec$ driven by an ideal compressor between stations 4 and 5. The compressor produces a low pressure at station 4 and very nearly ambient pressure at station 5 so that the gas exits the facility at station 6 at a low Mach number. At the condition shown, the pump pressure ratio is $P_{t5}/P_{t4} = 2$ and supersonic flow is established over an airfoil in the test section. The flow becomes subsonic after a shock downstream of station 3.



1) What is P_{t4}/P_{t1}?

2) Determine $f(M_4)$.

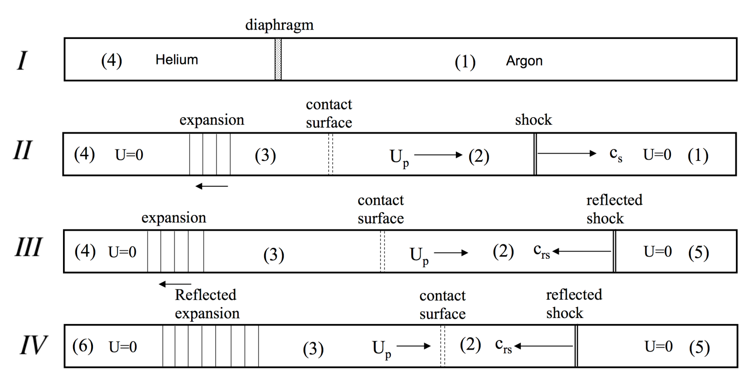
3) Assume the shock Mach number between stations 3 and 4 is 2.0. Determine P_{t3}/P_{t1}?

4) The jacks are used to reduce A_3. What value of A_3/A_1 will cause the wind tunnel to unstart?

5) How much power is required to drive the compressor?

6) Approximately what pump pressure ratio would be needed to reestablish supersonic flow in the test section?

Problem 2 – The designer of a 0.1meter diameter shock tube is concerned with large axial forces that can act on the tube during the time after the diaphragm is broken and waves are formed in the tube. In the diagram below, helium at high pressure in region 4 produces a Mach 5 shock in argon at pressure $P_1 = 10^5 N/m^2$. Both gases are initially at a temperature of $300K$.



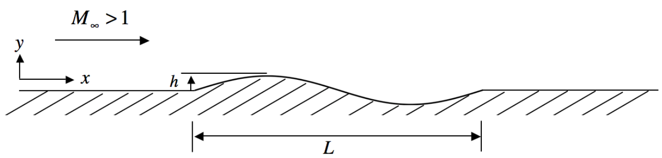
1) Determine the shock properties, U_2 / U_1, P_2 / P_1, a_2 / a_1, c_s, and the piston speed U_p.

2) Determine the shock tube pressure ratio P_4 / P_1 and the net force on the tube in state II.

3) Determine P_5 / P_2 and the net force after shock reflection, State III.

4) Determine a_3 / a_4, P_6 / P_3 and the net force after the expansion wave reflects, State IV.

Problem 3 – Inviscid supersonic flow along a flat wall encounters a small amplitude sinusoidal bump of amplitude h and length L, $y = hSin(2\pi x / L)$, where $h / L << 1$



1) Use thin airfoil theory to determine the pressure coefficient along the bump.

2) Use thin airfoil theory to determine the drag coefficient of the bump.

Problem 4 - The figure below shows a thin airfoil at a small angle of attack. The lift coefficient at $M_\infty = 0$ is $C_L = 0.2$. Suppose the Mach number is increased to $M_\infty = 0.5$.

1) Estimate the lift coefficient at $M_\infty = 0.5$.

2) Estimate the lift coefficient if the thickness of the airfoil is doubled at $M_\infty = 0.5$.