2024-2025 Spring
AE306 PH-2

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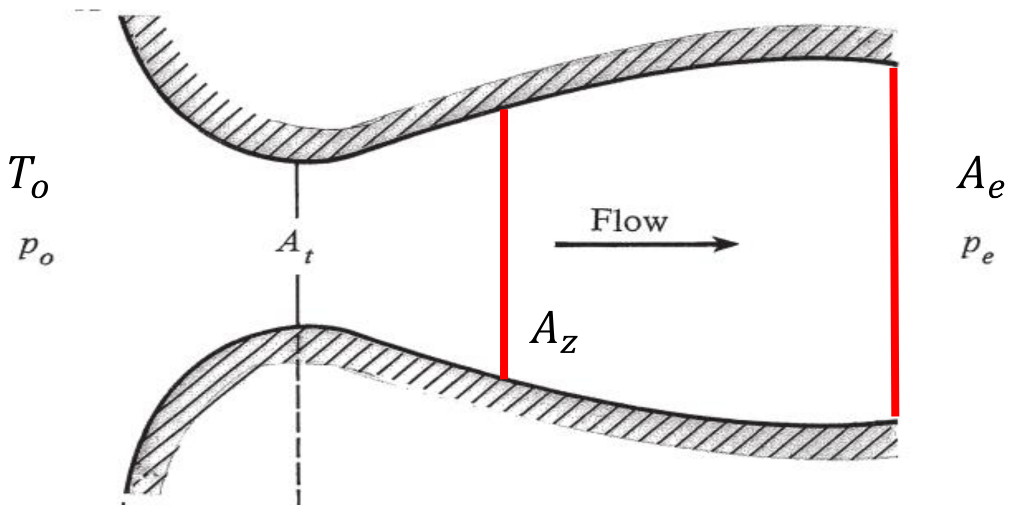
P1- Air flows through a convergent-divergent nozzle with given exit-to-throat area ratio of 1.4. The reservoir pressure and temperature are given as 1.10 atm and 405 K, respectively. If this nozzle opens to the standard sea level atmosphere, calculate the following:

a) Mach number at the nozzle exit. (Ans. M_e=0.37)
b) Mach number at the throat. (Ans. M_t=0.58)
c) Velocity at a cross-section (z) located at the downstream of the throat where the area ratio is 1.25. (Ans. u_z=168.44 m/s)
d) Mass flow rate through the nozzle for a throat area of 0.785 m2. (Ans. $\dot{m}$ = 145.03 kg/s)

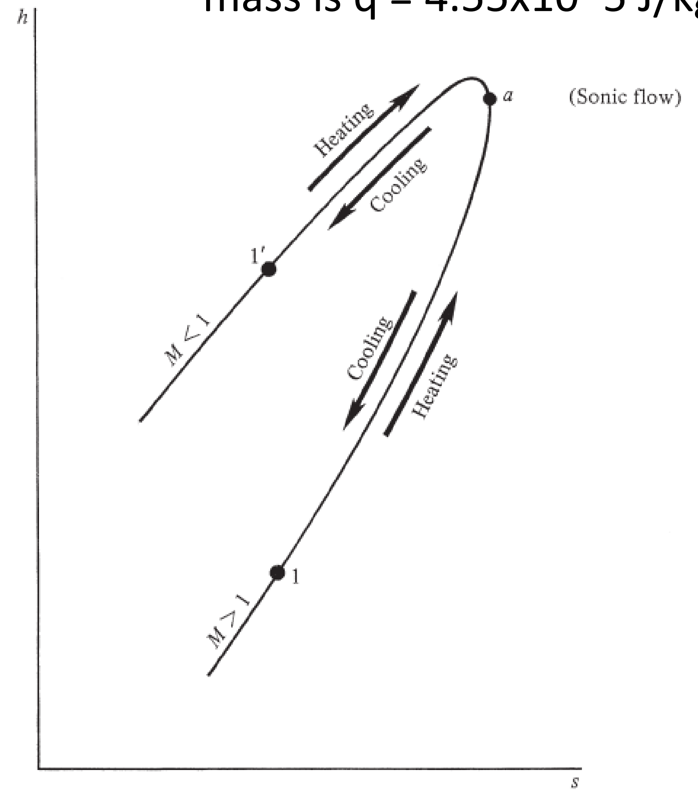


You can study Modern Compr. Chapter 5.4 for details.

P2- Air stream flows in a constant area duct where the inlet conditions are given as M_1= 0.32 , p_1=0.8 atm and T_1 =288 K.

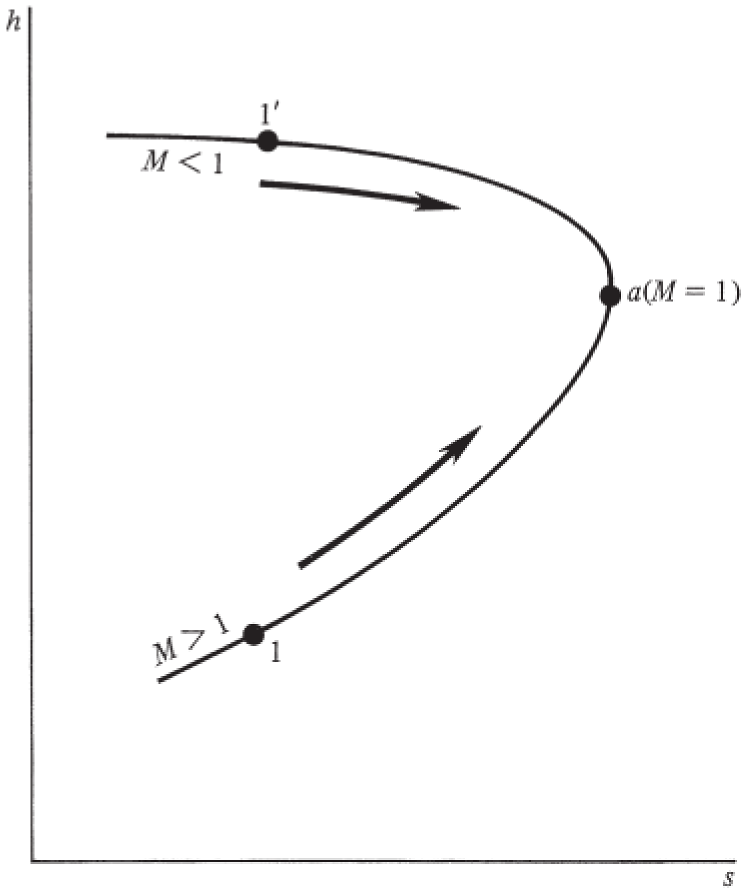
a) Find the heat addition per unit mass required in order to have choked flow at the downstream. (Ans. q_{cho}= 4.742 x 10^5 J/kg)

b) Calculate the downstream stagnant and static pressures and temperatures with if heat addition per unit mass is q = 4.55x10^5 J/kg. (Ans. $T_{o,2}$=746.86 K , $p_{o,2}$=0.7315 atm, T_2=656.17 K p_2=0.465 atm



You can study Modern Compr. Chapter 3.8 for details.

P3- Consider the adiabatic flow of air through a pipe of 60.96 mm inside diameter and 914.4 mm length. The inlet flow conditions are M_1 = 2.5, p_1=0.5 atm and T_1 =288.89 K. Assuming the local friction coefficient equals a constant of 0.005, calculate the following flow conditions at the exit: M_2, p_2, T_2, and $p_{o,2}$.



(Ans.
M_2 = 1.5
$p_2 = 1.03807$ atm
T_2 = 448.28 K
$p_{o,2}$ = 3.8108 atm)

You can study Modern Compr. Chapter 3.9 for details.

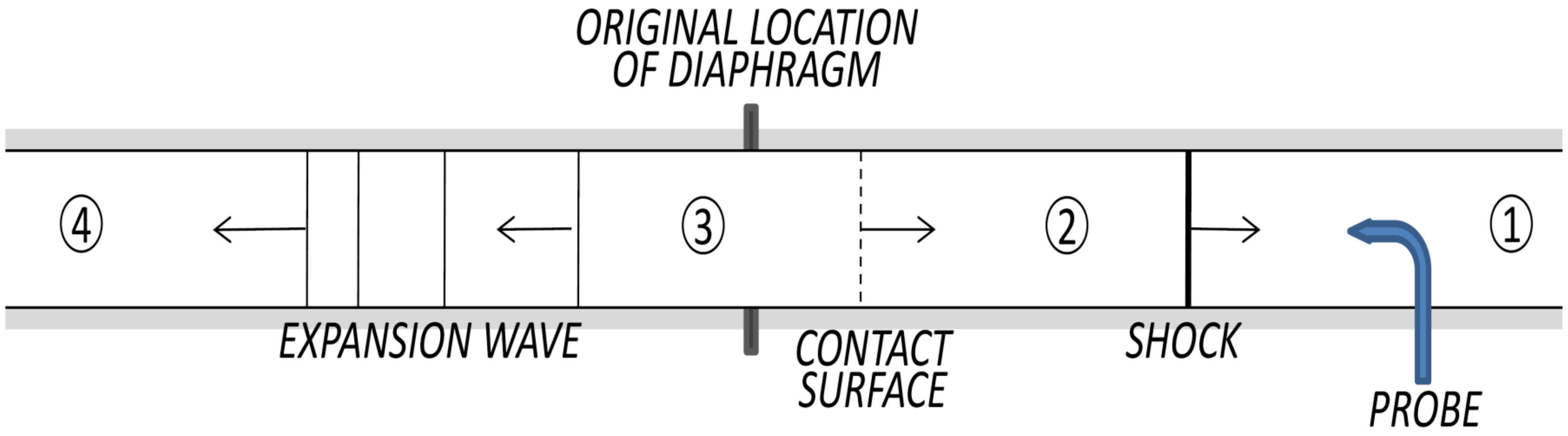
P3- Consider the adiabatic flow of air through a pipe of 60.96 mm inside diameter and 914.4 mm length. The inlet flow conditions are M_1 = 2.5, p_1=0.5 atm and T_1 =288.89 K. Assuming the local friction coefficient equals a constant of 0.005, calculate the following flow conditions at the exit: M_2, p_2, T_2, and $p_{o,2}$.

P4- Consider the flow on the driven side of a shock tube after the bursting of the diaphragm, as shown below. The air on the driven side is initially at 25 kPa and 300K, and the breaking of the diaphragm produces a shock with a pressure ratio P_2/P_1 of 4.00.

a. Determine the pressure, temperature and velocity (relative to the tube) of the driven gas just after the shock has passed. (Ans. p_2=100 kPa and T_2=480 K $u_p = 393.76\ m/s$)

b. A Pitot-static probe is fixed in the driven section of the shock tube. What will the Mach number of the flow over the tube be, and what static and stagnation pressures will it record, just after the shock passes? (Ans. p_{o2}=169.1 kPa and T_{o2}=557.76 K $M_{probe} = 0.9$)

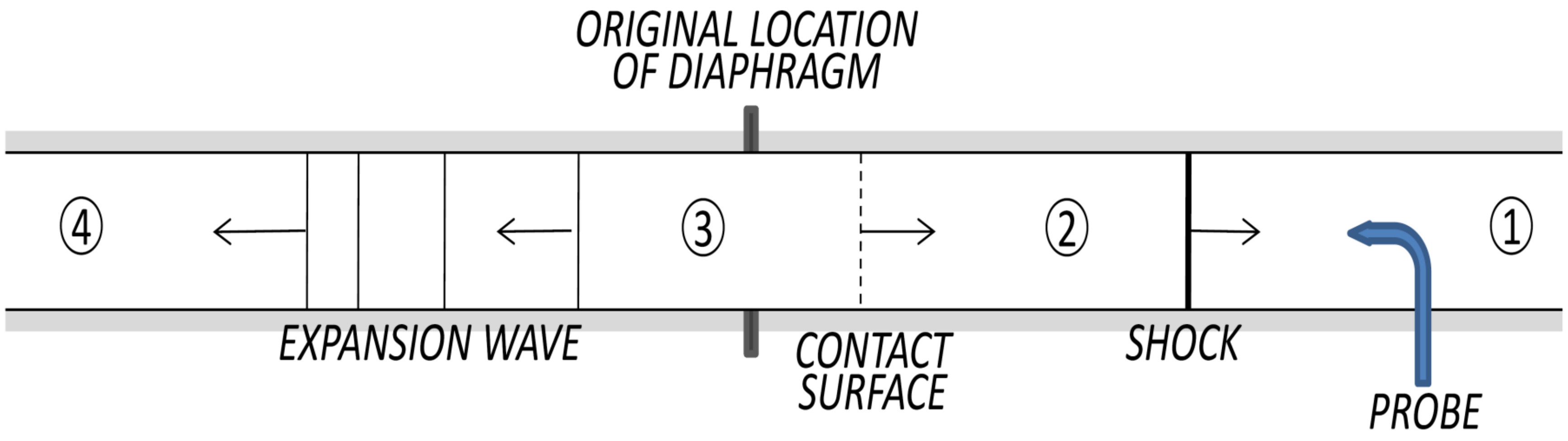
c. If there is a wall at the end of the shock tube, what should be the pressure, temperature and velocity at the region behind the reflected shock wave? (Ans. p_5=312.61 kPa and T_5=693.13 K $M_R = 1.68$)



You can study Modern Compr. Chapter 7.2 and 7.8 for details.

P4- Now consider the air on the driver side of the tube, during the same test, where the temperature is initially 480K. When the diaphragm breaks an expansion wave with a pressure ratio P_3/P_4=0.25 is produced.

d. Determine the speed of the leading edge of this wave and the temperature of the air in region 3. How should the mass motion velocity produced by the expansion wave compare to that generated by the shock? Estimate the initial pressure ratio $p4/p1$ across the diaphragm.
(Ans. $u_{LE_{expans}} = 439.16\ m/s$, T_3 = 323 K, p_4/p_1 = 16)



You can study Modern Compr. Chapter 7.2, 7.3 and 7.8 for details.

P5-Consider a velocity field where the x and y components of velocity are given by $\boldsymbol{u} = \frac{\boldsymbol{cy}}{(\boldsymbol{x^2+y^2})}$ and $\boldsymbol{v} = \frac{\boldsymbol{-cx}}{(\boldsymbol{x^2+y^2})}$, where c is a constant. Check whether this flow is irrotational or not. If it is, derive the velocity potential for this flow. Hint: Use polar coordinates for easiness.

(Ans. Since $\nabla \times \vec{V} = 0$ flow is irrotational. $\phi = -c\theta + const$)

You can study Modern Compr. Chapter 8.2 or your old Aerodynamics 1 notes for details.