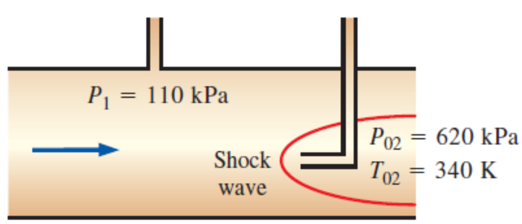
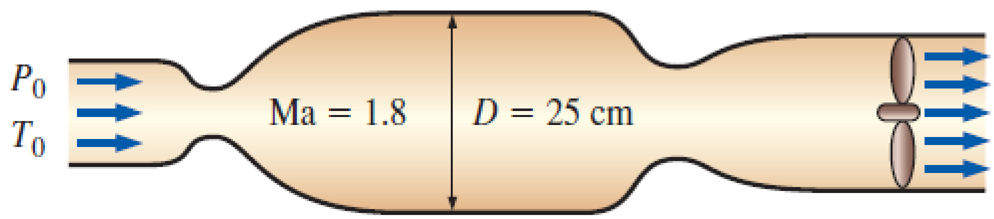
SPC 407
Sheet 8
Compressible Flow – Review

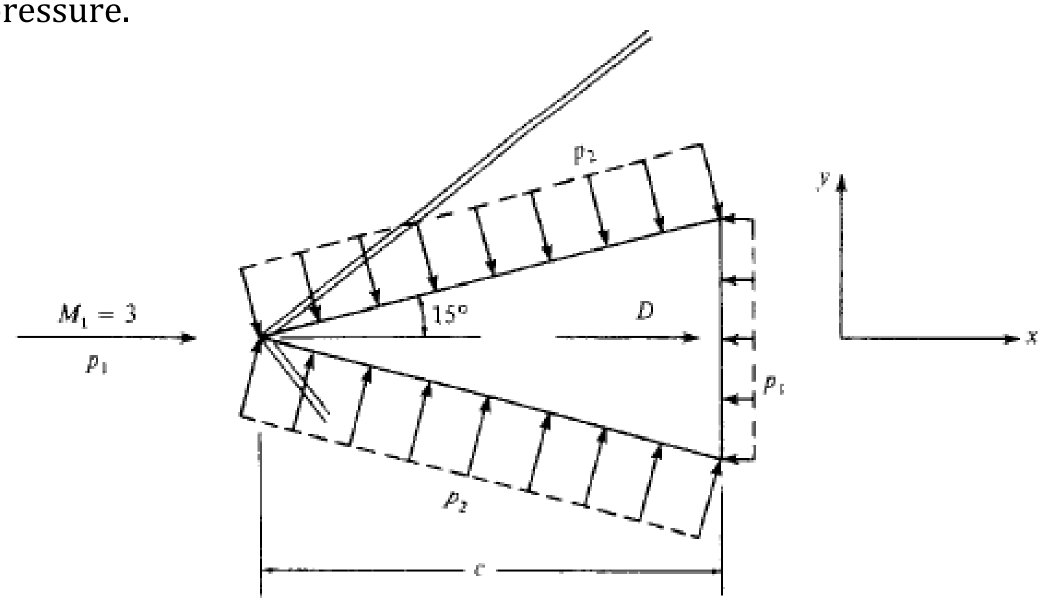
1. The thrust developed by the engine of a Boeing 777 is about 380 kN. Assuming choked flow in the nozzles, determine the mass flow rate of air through the nozzle. Take the ambient conditions to be 220 K and 40 kPa.
2. A stationary temperature probe inserted into a duct where air is flowing at 190 m/s reads 858C. What is the actual temperature of the air?
3. Nitrogen enters a steady-flow heat exchanger at 150 kPa, 108 C, and 100 m/s, and it receives heat in the amount of 150 kJ/kg as it flows through it. The nitrogen leaves the heat exchanger at 100 kPa with a velocity of 200 m/s. Determine the stagnation pressure and temperature of the nitrogen at the inlet and exit states.
4. A subsonic airplane is flying at a 5000-m altitude where the atmospheric conditions are 54 kPa and 256 K. A Pitot static probe measures the difference between the static and stagnation pressures to be 16 kPa. Calculate the speed of the airplane and the flight Mach number.
5. Nitrogen enters a converging–diverging nozzle at 620 kPa and 310 K with a negligible velocity, and it experiences a normal shock at a location where the Mach number is Ma = 3.0. Calculate the pressure, temperature, velocity, Mach number, and stagnation pressure downstream of the shock. Compare these results to those of air undergoing a normal shock at the same conditions.
6. In compressible flow, velocity measurements with a Pitot probe can be grossly in error if relations developed for incompressible flow are used. Therefore, it is essential that compressible flow relations be used when evaluating flow velocity from Pitot probe measurements. Consider supersonic flow of air through a channel. A probe inserted into the flow causes a shock wave to occur upstream of the probe, and it measures the stagnation pressure and temperature to be 620 kPa and 340 K, respectively. If the static pressure upstream is 110 kPa, determine the flow velocity.



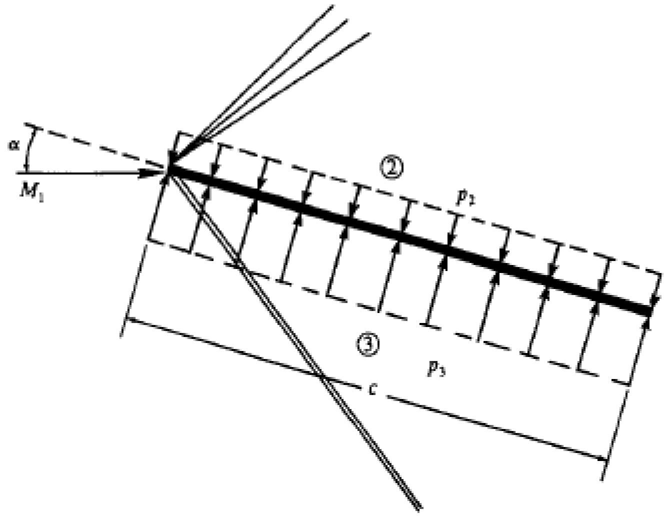
7. Design a 1-m-long cylindrical wind tunnel whose diameter is 25 cm operating at a Mach number of 1.8. Atmospheric air enters the wind tunnel through a converging– diverging nozzle where it is accelerated to supersonic velocities. Air leaves the tunnel through a converging–diverging diffuser where it is decelerated to a very low velocity before entering the fan section. Disregard any irreversibilities. Specify the temperatures and pressures at several locations as well as the mass flow rate of air at steady-flow conditions. Why is it often necessary to dehumidify the air before it enters the wind tunnel?



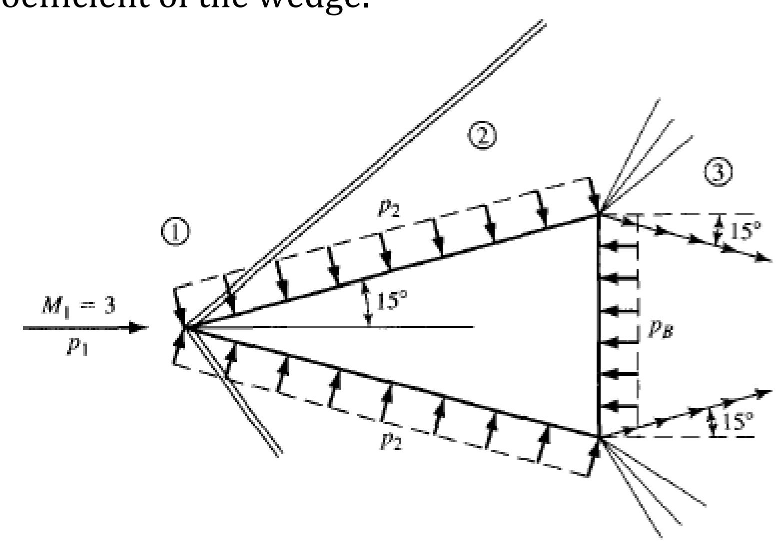
8. A 10" half-angle wedge is placed in a "mystery flow" of unknown Mach number. Using a Schlieren system, the shock wave angle is measured as 44". What is the free-stream Mach number?
9. Consider a 15" half-angle wedge at zero angle of attack. Calculate the pressure coefficient on the wedge surface in a Mach 3 flow of air.
10. Consider a 15" half-angle wedge at zero angle of attack in a Mach 3 f ow of air. Calculate the drag coefficient. Assume that the pressure exerted over the base of the wedge, the base pressure, is equal to the free-stream pressure.



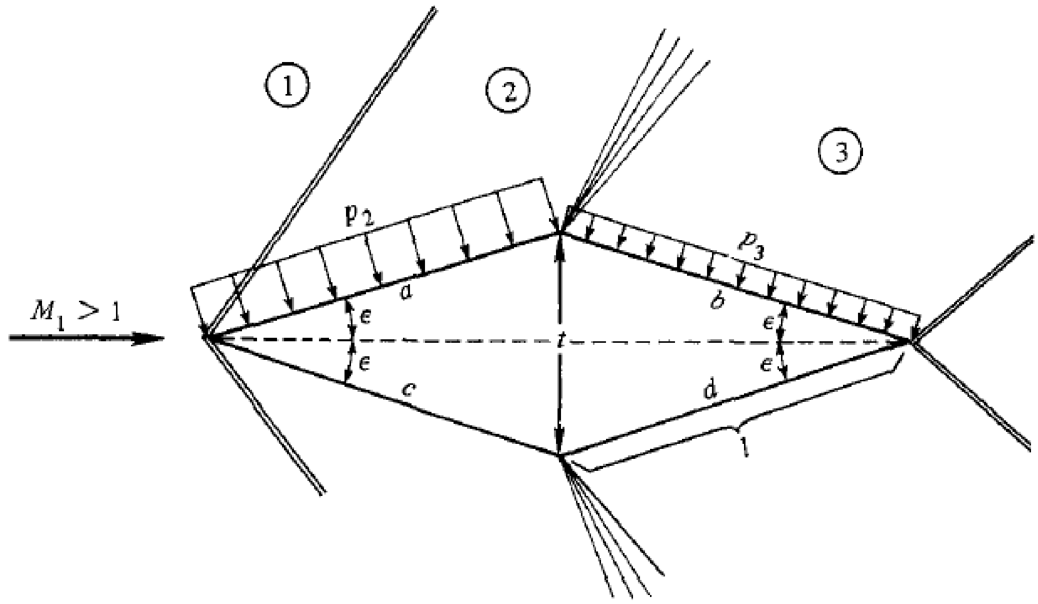
11. Consider an infinitely thin flat plate at a 5° angle of attack in a Mach 2.6 free stream. Calculate the lift and drag coefficients.



12. Consider the 15° half-angle wedge shown in Fig. We make the assumptions that (1) the flow separates at the comers, with the streamlines trailing downstream of the corners deflected toward the base at an angle of 15° from the horizontal, as shown in Fig, and (2) the base pressure p_B is the arithmetic average between the pressure downstream of the expansion waves, p_3, and the freestream pressure, p_1. i.e., $p_B = 1/2(p_3 + p_l)$. We emphasize that both assumptions are purely arbitrary; they represent a qualitative model of the flow with arbitrary numbers, and do not necessarily reflect the actual quantitative flowfield values that actually exist in the base flow region. Based on the model flow sketched in Fig. calculate the drag coefficient of the wedge.



13. Calculate the lift and drag (in pounds) on a symmetrical diamond airfoil of semiangle $\varepsilon = 15$ (see Fig.) at an angle of attack to the free stream of 5° when the upstream Mach number and pressure are 2.0 and 2116 lb/ft^2, respectively. The maximum thickness of the airfoil is t = 0.5 ft. Assume a unit length of 1 ft in the span direction (perpendicular to the page in Fig.).



14. Consider a flat plate with a chord length (from leading to trailing edge) of 1 m. The free-stream flow properties are $M_1 = 3$, $p_1 = 1$ atm, and $T_1 = 270$ K. Tabulate and plot on graph paper these properties as functions of angle of attack from 0 to 30° (use increments of 5°):
    a. Pressure on the top surface
    b. Pressure on the bottom surface
    c. Temperature on the top surface
    d. Temperature on the bottom surface
    e. Lift per unit span
    f. Drag per unit span
    g. Lift/drag ratio

15. Calculate the drag coefficient for a wedge with a 20° half-angle at Mach 4. Assume the base pressure is free-stream pressure.