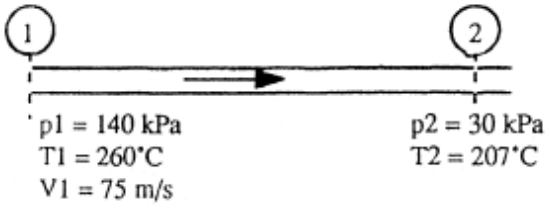
Gas Dynamics

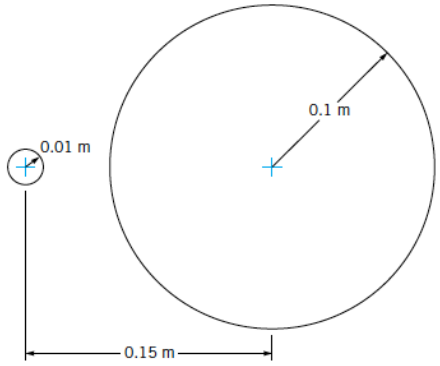
Assignment #1: Speed of sound

1. An ideal gas flows adiabatically through a duct. At section 1, p1 = 140 kPa, T1 = 260°C, and V1 = 75 m/s. Farther downstream, p2 = 30 kPa and T2 = 207°C. Calculate V2 in m/s if the gas is (a) air, k = 1.4, and (b) argon, k = 1.67.

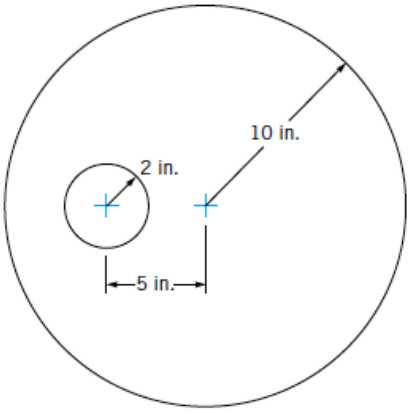


2. Helium (k=1.66, R=2077 j/kg.K) at 300°C and 200 kPa, in a closed container, is cooled to a pressure of 100 kPa. Estimate the new temperature, in °C.
3. A certain aircraft flies at the same Mach number regardless of its altitude. Compared to its speed at 12000-m Standard Altitude (T=216 K), it flies 127 km/h faster at sea level (T=288 K). Determine its Mach number.
4. At 300°C and 1 atm, estimate the speed of sound of (a) nitrogen (k=1.4, R=297); (b) hydrogen (k=1.41, R=4124); (c) helium (k=1.66, R=2077 J/kg.K); (d) steam (k=1.33, R=461); and (e) uranium hexafluoride 238UF6 (k = 1.06, molecular weight=352).
5. A weak pressure wave (sound wave), with a pressure change $\Delta p \approx 40$ Pa, propagates through still air at 20°C and 1 atm. Estimate (a) the density change; (b) the temperature change; and (c) the velocity change across the wave. Use the relations we derived in lecture #1 ($\Delta p \approx \rho C \Delta V$, $C\, d\rho = \rho\, dV$).
6. The Concorde aircraft flies at Ma ≈ 2.3 at 11-km standard altitude (T=216 K). Estimate the temperature in °C at the front stagnation point. At what Mach number would it have a front stagnation point temperature of 450°C?
7. A gas flows at V = 200 m/s, p = 125 kPa, and T = 200°C. For (a) air and (b) helium, compute the maximum pressure and the maximum velocity attainable by expansion or compression.
8. CO2 (k=1.3, R=189 j/kg.K) expands isentropically through a duct from p1 = 125 kPa and T1 = 100°C to p2 = 80 kPa and V2 = 325 m/s. Compute (a) T2; (b) M2; (c) To; (d) p_0; (e) V1; and (f) M1.

9. At a given instant of time, two pressure waves, each moving at the speed of sound, emitted by a point source moving with constant velocity in a fluid at rest are shown in the Figure. Determine the Mach number involved and indicate with a sketch the instantaneous location of the point source.



10. At a given instant of time, two pressure waves, each moving at the speed of sound, emitted by a point source moving with constant velocity in a fluid at rest, are shown in the Figure. Determine the Mach number involved and indicate with a sketch the instantaneous location of the point source.



11. List how the following variables change with the increase in cross section area at subsonic and supersonic flows: pressure, temperature, velocity, density, and Mach number.