1. Water flows past a flat plate with an upstream velocity of \( U = 0.02 \text{ m/s} \). Determine the water velocity a distance of 10 mm from the plate at distances of \( x = 1.5 \text{ m} \) and \( x = 15 \text{ m} \) from the leading edge. (*This problem requires to use Blasius solution as shown in table 9.1*)

2. Determine, in British Gravitational Units, nominal values of \( c_p \) and \( c_v \) for (a) air, (b) carbon dioxide, (c) helium. Use information provided in table 1.7

3. Helium is compressed isothermally from 121 kPa (abs) to 301 kPa (abs). Determine the entropy change associated with this process.

4. 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 Fig. P11.23. Determine the Mach number involved and indicate with a sketch the instantaneous location of the point source.
Water flows past a flat plate with an upstream velocity of \( U = 0.02 \text{ m/s}\). Determine the water velocity a distance of 10 mm from the plate at distances of \( x = 1.5 \text{ m} \) and \( x = 15 \text{ m} \) from the leading edge.

From the Blasius solution for boundary layer flow on a flat plate, \( u = U f'(\eta) \), where \( \eta \), the similarity variable, is
\[
\eta = \sqrt{\frac{U}{\nu x}}.
\]
Values of \( f'(\eta) \) are given in Table 9.1.

Since \( Re_x = \frac{U x}{\nu} = \frac{0.02 \text{ m/s}}{1.12 \times 10^{-6} \text{ m}^2/\text{s}} (1.5 \text{ m}) = 2.68 \times 10^5 \) is less than the critical \( Re_{cr} = 5 \times 10^5 \), it follows that the boundary layer flow is laminar.

At \( x_1 = 1.5 \text{ m} \) and \( y = 10 \times 10^{-3} \text{ m} \) we obtain:
\[
\eta_1 = (10 \times 10^{-3} \text{ m}) \sqrt{\frac{0.02 \text{ m/s}}{(1.12 \times 10^{-6} \text{ m}^2/\text{s}) (1.5 \text{ m})}} = 1.091
\]
Linear interpolation from Table 9.1 gives:
\[
f' = 0.2647 + \frac{(0.3938 - 0.2647)}{(1.2 - 0.8)} (1.091 - 0.8) = 0.359
\]
Hence,
\[
u_1 = U f'(\eta_1) = (0.02 \text{ m/s})(0.359) = 0.00718 \text{ m/s}
\]

Similarly, at \( x_2 = 15 \text{ m} \) and \( y = 10 \times 10^{-3} \text{ m} \) we obtain:
\[
\eta_2 = (10 \times 10^{-3} \text{ m}) \sqrt{\frac{0.02 \text{ m/s}}{(1.12 \times 10^{-6} \text{ m}^2/\text{s}) (1.5 \text{ m})}} = 0.345
\]
Linear interpolation from Table 9.1 gives:
\[
f' = 0.0 + \frac{(0.1328 - 0.0)}{(0.8 - 0.4)} (0.345 - 0.0) = 0.145
\]
Hence,
\[
u_2 = U f'(\eta_2) = (0.02 \text{ m/s})(0.145) = 0.0029 \text{ m/s}
\]
11.2 Determine, in EE units, nominal values of $c_p$ and $c_v$ for: (a) air, (b) carbon dioxide, (c) helium, (d) hydrogen, (e) methane, (f) nitrogen, (g) oxygen. Use information provided in Table 1.7.

For an ideal gas Eqs. 11.14 and 11.15 may be used to calculate values of $c_p$ and $c_v$. Thus

$$c_p = \frac{Rk}{k-1} \quad \text{and} \quad c_v = \frac{R}{k-1}$$

To determine $c_p$ and $c_v$ values in EE units, BG unit information and the conversion, 1 slug = 32.174 lbm, are used.

For British Gravitational Units, values of the gas constant, $R$, and specific heat ratio, $k$, are listed in Table 1.7.

(a) For air

$$c_p = \frac{(7716 \text{ ft. lb/slug} \cdot \degree R)}{(1.4)} \times \frac{1}{(1.4 - 1)(32.174 \text{ lbm/slug})} = 187 \frac{\text{ft. lb}}{\text{lbm} \cdot \degree R}$$

$$c_v = \frac{(7716 \text{ ft. lb/slug} \cdot \degree R)}{(1.4 - 1)(32.174 \text{ lbm/slug})} = 133 \frac{\text{ft. lb}}{\text{lbm} \cdot \degree R}$$

(b) For carbon dioxide

$$c_p = \frac{(1130 \text{ ft. lb/slug} \cdot \degree R)}{(1.3)} \times \frac{1}{(1.3 - 1)(32.174 \text{ lbm/slug})} = 152 \frac{\text{ft. lb}}{\text{lbm} \cdot \degree R}$$

$$c_v = \frac{(1130 \text{ ft. lb/slug} \cdot \degree R)}{(1.3 - 1)(32.174 \text{ lbm/slug})} = 117 \frac{\text{ft. lb}}{\text{lbm} \cdot \degree R}$$

(c) For helium

$$c_p = \frac{(12,420 \text{ ft. lb/slug} \cdot \degree R)}{(1.66)} \times \frac{1}{(1.66 - 1)(32.174 \text{ lbm/slug})} = 971 \frac{\text{ft. lb}}{\text{lbm} \cdot \degree R}$$

$$c_v = \frac{(12,420 \text{ ft. lb/slug} \cdot \degree R)}{(1.66 - 1)(32.174 \text{ lbm/slug})} = 585 \frac{\text{ft. lb}}{\text{lbm} \cdot \degree R}$$
11.6 Helium is compressed isothermally from 121 kPa (abs) to 301 kPa (abs). Determine the entropy change associated with this process.

Eq. 11.22 may be used to evaluate the entropy change for this isothermal process. Thus,

\[ s_2 - s_1 = -R \ln \left( \frac{P_2}{P_1} \right) = -\left( 2077 \frac{J}{kg.K} \right) \ln \left( \frac{301 kPa (abs)}{121 kPa (abs)} \right) \]

and

\[ s_2 - s_1 = -1890 \frac{J}{kg.K} \]

11.23 At a given instant of time, two of the 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 Fig. P11.23. Determine the Mach number involved and indicate with a sketch the instantaneous location of the point source.

The Mach number associated with the motion of the point source involved in the sketch above is easily obtained with Eq. 11.39 as shown below.

\[ Ma = \frac{1}{\sin \varphi} \]

From the sketch above we note that

\[ \sin \varphi = \frac{0.01 m}{0.1 m} = 0.1 \]

Thus

\[ 0.01m \times 0.15m + 0.1m = \]

or

\[ l = \frac{(0.01m)(0.15m)}{0.09m} = 0.0167 m \]

And

\[ \sin \varphi = \frac{0.01 m}{0.0167 m} = 0.599 \]

Thus

\[ Ma = \frac{1}{\sin \varphi} = \frac{1}{0.599} = 1.67 \]