Solutions for Modern Compressible Flow 4th Edition by Anderson

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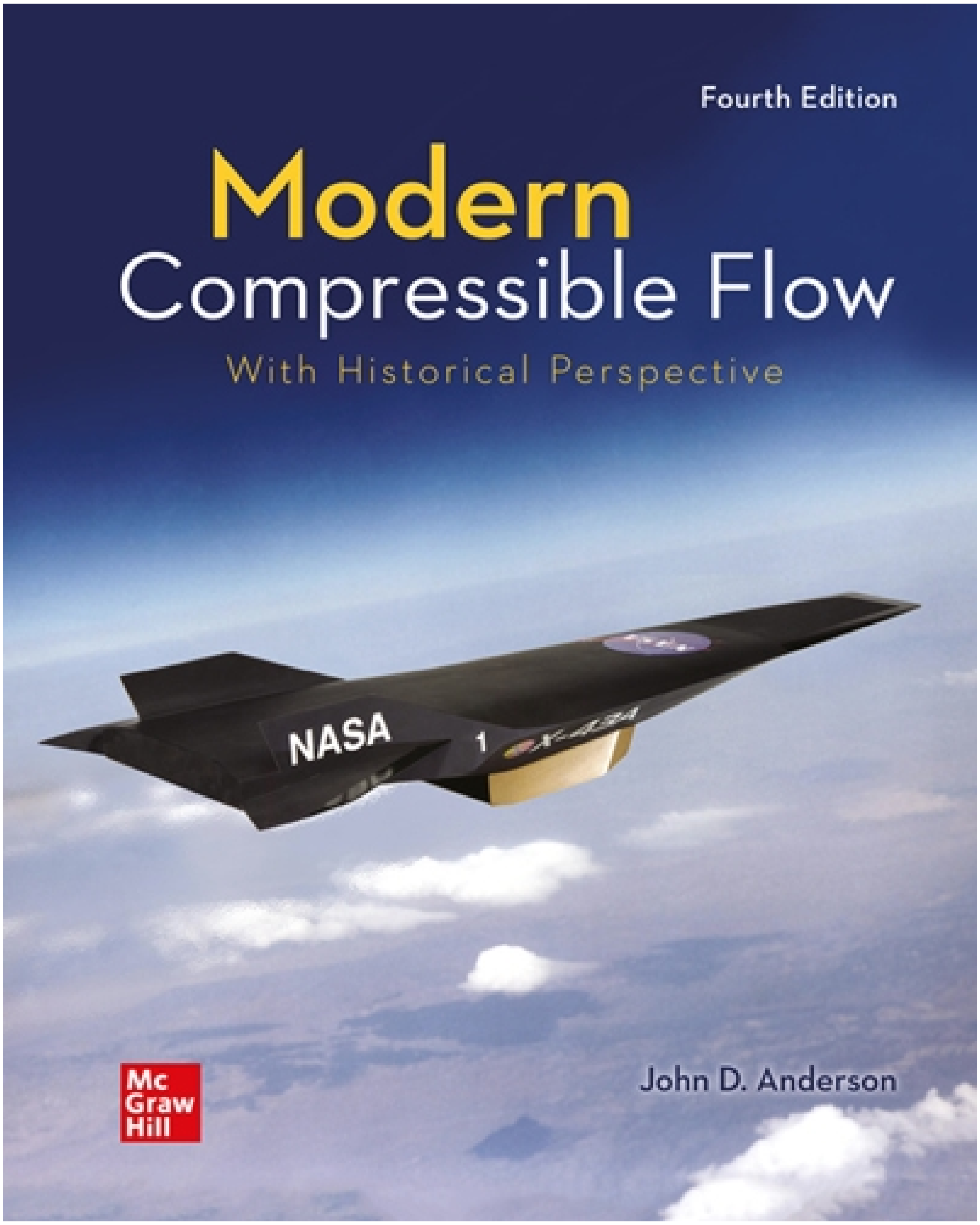

Solutions

CHAPTER 1

1.1 $\rho = \dfrac{p}{RT} = \dfrac{(5.6)(2116)}{(1716)(850)} = \boxed{0.00812 \text{ slug/ft}^3}$

$v = \dfrac{1}{\rho} = \boxed{123 \text{ ft}^3\text{/slug}}$

1.2 $\rho = \dfrac{p}{RT} = \dfrac{(10)(1.01 \text{ x } 10^5)}{(287)(320)} = \boxed{11.0 \text{ kg/m}^3}$

$n = \dfrac{p}{RT} = \dfrac{(10)(1.01 \text{ x } 10^5)}{(1.38 \text{ x } 10^{-23})(320)} = \boxed{2.87 \text{ x } 10^{26}\text{/m}^3}$

$\eta = \dfrac{pv}{RT} = \dfrac{p}{\rho RT} = \dfrac{(10)(1.01 \text{ x } 10^5)}{(11.0)(8314)(320)} = 0.0345 \dfrac{\text{kg} - \text{mole}}{\text{kg}}$

1.3 From the definition of enthalpy,

$h = e + p\,v = e + RT$ (A1)

For a calorically perfect gas, this becomes

$c_p\,T = c_v\,T + RT$, or $\boxed{c_p - c_v = R}$

For a thermally perfect gas, Eq. (A1) is first differentiated

$dh = de + Rdt$

or,

$c_p\,dT = c_v\,dT = Rdt$

or,

$\boxed{c_p - c_v = R}$

1.4 $s_2 - s_1 = c_p\,\ell n \dfrac{T_2}{T_1} - R\,\ell n \dfrac{p_2}{p_1}$

(a) R = 1716 ft-lb/slug°R

$$c_p = \frac{\gamma R}{\gamma - 1} = \frac{(1.4)(1716)}{0.4} = 6006 \text{ ft-lb/slug°R}$$

$$s_2 - s_1 = (6006)\ \ell n\ (1.687) - (1716)\ \ell n\ 4.5$$

$$s_2 - s_1 = \boxed{559.9 \text{ ft-lb/slug°R}}$$

(b) R = 287 joule/kg°K

$$c_p = \frac{\gamma R}{\gamma - 1} = \frac{(1.4)(287)}{0.4} = 1004.5 \text{ joule/kg°K}$$

$$s_2 - s_1 = (1004.5)\ \ell n\ (1.687) - 287\ \ell n\ (4.5)$$

$$s_2 - s_1 = \boxed{93.6 \text{ joule/kg°K}}$$

1.5 $$\frac{p_2}{p_1} = \left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}}$$

$$p_2 = p_1 \left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}} = 1800\ (400/500)^{\frac{1.4}{0.4}}$$

$$p_2 = \boxed{824.3 \text{ lb/ft}_2}$$

$$\rho_2 = \frac{p_2}{RT_2} = \frac{824.3}{(1716)(400)} = \boxed{0.0012 \text{ slug/ft}^3}$$

1.6 Volume of room = (20)(15)(8) = 2400 ft^3

Standard sea level density = 0.002377 $slug/ft^3$

Mass of air = (0.002377)(2400) = $\boxed{5.70 \text{ slug}}$

Weight = Mass x acceleration of gravity = (5.7)(32.2) = $\boxed{184 \text{ lb}}$

1.7

(a) $dp = -\rho V dV$

and $d\rho = \rho\, \tau\, dp$, or $dp = \dfrac{d\rho}{\rho\tau}$

Combining:

$$\frac{d\rho}{\rho\tau} = -\rho\, VdV$$

$$d\rho = -\,\tau\, p^2\, VdV$$

$$\frac{d\rho}{\rho} = -\,\tau\, \rho\, VdV$$

$$\frac{d\rho}{\rho} = -\,\tau\, \rho\, V^2\, \frac{dV}{V}$$

(b) $\tau_s = \dfrac{1}{\gamma p} = \dfrac{1}{(1.4)(1.01\ \text{x}\ 10^5)} = 7.07 \text{ x } 10^{-6}\ m^2/N$

$$\frac{d\rho}{\rho} = \tau_s\, \rho\, V^2\, \frac{dV}{V} = -\,(7.07 \text{ x } 10^{-6})(1.23)(10)^2(0.01)$$

$$\frac{d\rho}{\rho} = \boxed{-\,8.7 \text{ x } 10^{-6}}$$

(c) Here, $\dfrac{d\rho}{\rho}$ will be larger by the ratio $\left(\dfrac{1000}{10}\right)^2$.

$$\frac{d\rho}{\rho} = (-\,8.7 \text{ x } 10^{-6})\left(\frac{1000}{10}\right)^2 = \boxed{-\,8.7 \text{ x } 10^{-2}}$$

Comment: By increasing the velocity of a factor of 100, the fractional change in density is increased by factor of 10^4. This is just another indication of why high-speed flows must be treated as compressible.