

***Modern Compressible Flow 4th edition Anderson
Solutions Manual***

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CHAPTER 1

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

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

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

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

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

1.3 From the definition of enthalpy,

$$h = e + p v = e + RT \tag{A1}$$

For a calorically perfect gas, this becomes

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

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

$$dh = de + R dt$$

or,

$$c_p dT = c_v dT = R dt$$

or,

$$\boxed{c_p - c_v = R}$$

$$1.4 \quad s_2 - s_1 = c_p \ln \frac{T_2}{T_1} - R \ln \frac{p_2}{p_1}$$

(a) $R = 1716 \text{ ft-lb/slug}^\circ\text{R}$

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

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

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

(b) $R = 287 \text{ joule/kg}^\circ\text{K}$

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

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

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

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 = $(20)(15)(8) = 2400 \text{ ft}^3$

$$\text{Standard sea level density} = 0.002377 \text{ slug/ft}^3$$

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

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

1.7

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

$$\text{and} \quad d\rho = \rho \tau dp, \text{ or } dp = \frac{d\rho}{\rho \tau}$$

Combining:

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

$$d\rho = -\tau \rho^2 V dV$$

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

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

$$(b) \quad \tau_s = \frac{1}{\mu p} = \frac{1}{(1.4)(1.01 \times 10^5)} = 7.07 \times 10^{-6} \text{ m}^2/\text{N}$$

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

$$\frac{d\rho}{\rho} = \boxed{-8.7 \times 10^{-6}}$$

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

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

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.