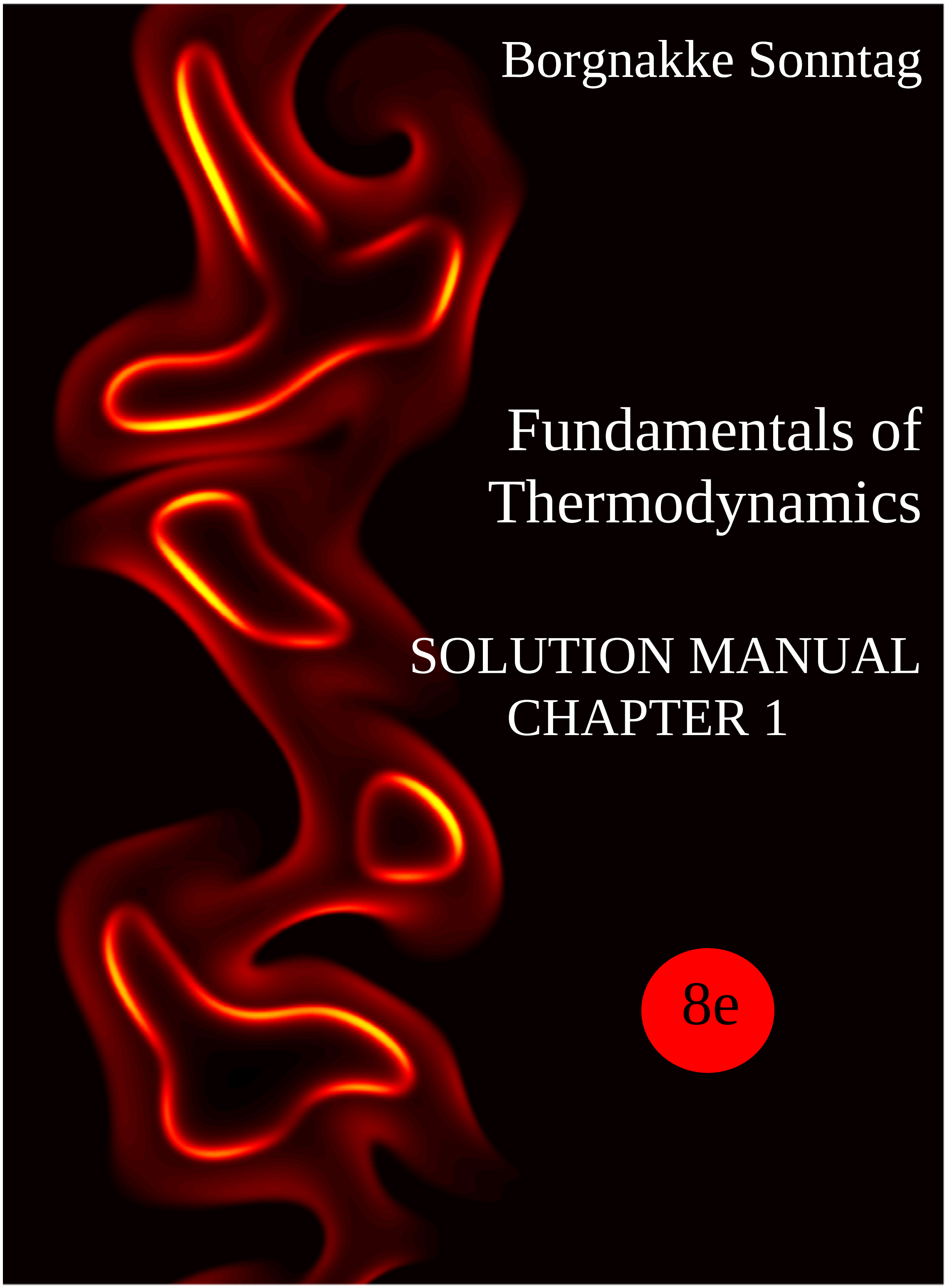


Borgnakke Sonntag

Fundamentals of Thermodynamics

SOLUTION MANUAL CHAPTER 1

8e

Updated June 2013

CONTENT CHAPTER 1

In-Text Concept Questions

1.87

A car of mass 1775 kg travels with a velocity of 100 km/h. Find the kinetic energy. How high should it be lifted in the standard gravitational field to have a potential energy that equals the kinetic energy?

Solution:

Standard kinetic energy of the mass is

$$KE = \tfrac{1}{2}\, m\, \mathbf{V}^2 = \tfrac{1}{2} \times 1775 \text{ kg} \times \left(\frac{100 \times 1000}{3600}\right)^2 \text{ m}^2/\text{s}^2$$

$$= \tfrac{1}{2} \times 1775 \times 27.778 \text{ Nm} = 684\,800 \text{ J}$$

$$= \mathbf{684.8\ kJ}$$

Standard potential energy is

$$POT = mgh$$

$$h = \tfrac{1}{2}\, m\, \mathbf{V}^2 / mg = \frac{684\,800 \text{ Nm}}{1775 \text{ kg} \times 9.807 \text{ m/s}^2} = \mathbf{39.3\ m}$$

2.42

You want a pot of water to boil at 105^{o}C. How heavy a lid should you put on the 15 cm diameter pot when P_{atm} = 101 kPa?

Solution:

Table B.1.1 at 105^{o}C : P_{sat} = 120.8 kPa

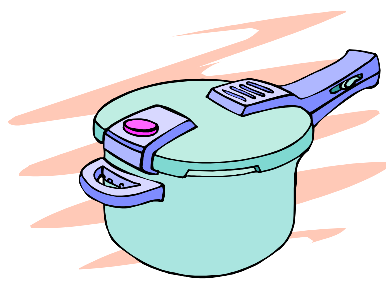
$$A = \frac{\pi}{4} D^2 = \frac{\pi}{4} 0.15^2 = 0.01767 \text{ m}^2$$

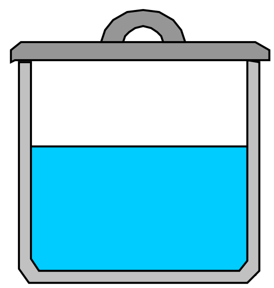
$$F_{net} = (P_{sat} - P_{atm})\, A = (120.8 - 101) \text{ kPa} \times 0.01767 \text{ m}^2$$
$$= 0.3498 \text{ kN} = 350 \text{ N}$$

$$F_{net} = m_{lid}\, g$$

$$m_{lid} = F_{net}/g = \frac{350}{9.807} \frac{\text{N}}{\text{m/s}^2} = \mathbf{35.7\ kg}$$

Some lids are clamped on, the problem deals with one that stays on due to its weight.





3.132

We want to find the change in u for carbon dioxide between 50^{o}C and 200^{o}C at a pressure of 10 MPa. Find it using ideal gas and Table A.5 and repeat using the B section table.

Solution:

Using the value of C_{vo} for CO_2 from Table A.5,

$\Delta u = C_{vo}\,\Delta T$ = 0.653 kJ/kg-K × (200 – 50) K = **97.95 kJ/kg**

Using values of u from Table B3.2 at 10 000 kPa, with linear interpolation between 40^{o}C and 60^{o}C for the 50^{o}C value,

$\Delta u = u_{200} - u_{50}$ = 437.6 – 230.9 = **206.7 kJ/kg**

Note: Since the state 50^{o}C, 10 000 kPa is in the dense-fluid supercritical region, a linear interpolation is quite inaccurate. The proper value for u at this state is found from the CATT software to be 245.1 instead of 230.9. This results is

$\Delta u = u_{200} - u_{50}$ = 437.6 – 245.1 = **192.5 kJ/kg**

5.53

Find the maximum coefficient of performance for the refrigerator in your kitchen, assuming it runs in a Carnot cycle.

Solution:

The refrigerator coefficient of performance is

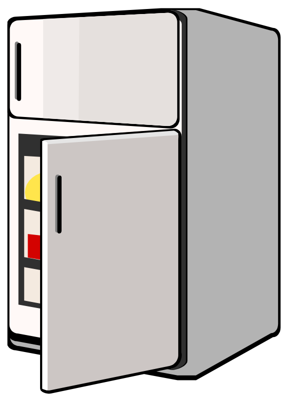
$$\beta = Q_L/W = Q_L/(Q_H - Q_L) = T_L/(T_H - T_L)$$

Assuming $T_L \sim 0°C$, $T_H \sim 35°C$,

$$\beta \le \frac{273.15}{35 - 0} = \mathbf{7.8}$$

Actual working fluid temperatures must be such that

$$T_L < T_{refrigerator} \quad \text{and} \quad T_H > T_{room}$$



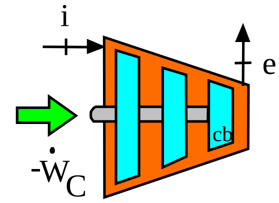
A refrigerator does not operate in a Carnot cycle. The actual vapor compression cycle is examined in Chapter 9.

7.86

A compressor in a commercial refrigerator receives R-410A at -25^{o}C and x = 1. The exit is at 1000 kPa and 20^{o}C. Is this compressor possible?

Solution:

C.V. Compressor, steady state, single inlet and exit flow. For this device we also assume no heat transfer and $Z_i = Z_e$



From Table B.4.1 : h_i = 269.77 kJ/kg, s_i = 1.0893 kJ/kg-K

From Table B.4.2 : h_e = 295.49 kJ/kg, s_e = 1.073 kJ/kg-K

Entropy gives

$$s_{gen} = s_e - s_i - \int dq/T = 1.073 - 1.0893 - \int dq/T = \text{negative}$$

The result is negative unless dq is negative (it should go out, but T < T ambient) so this compressor is **impossible**

9.99

A refrigerator has a steady flow of R-410A as saturated vapor at –20°C into the adiabatic compressor that brings it to 1400 kPa. After the compressor, the temperature is measured to be 60°C. Find the actual compressor work and the actual cycle coefficient of performance.

Solution:

Table B.4.1: $h_1 = 271.89$ kJ/kg, $s_1 = 1.0779$ kJ/kg K

$P_2 = P_3 = 1400$ kPa, $T_3 = 18.88°C$, $h_4 = h_3 = h_f = 87.45$ kJ/kg

$h_{2\,ac} = 330.07$ kJ/kg

C.V. Compressor (actual)

Energy Eq.: $w_{C\,ac} = h_{2\,ac} - h_1 = 330.07 – 271.89 =$ **58.18 kJ/kg**

C.V. Evaporator

Energy Eq.: $q_L = h_1 - h_4 = h_1 - h_3 = 271.89 – 87.45 = 184.44$ kJ/kg

$$\beta = \frac{q_L}{w_{C\,ac}} = \frac{184.44}{58.18} = \mathbf{3.17}$$

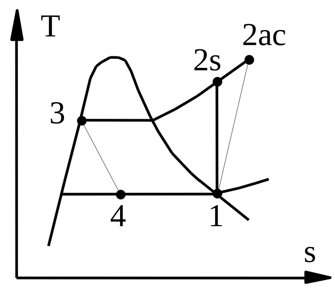
Ideal refrigeration cycle
with actual compressor

$T_{cond} = 18.88^oC = T_{sat\ 1400\ kPa}$

$T_2 = 60^oC$

$T_{evap} = -20^oC = T_1$

Properties from Table B.4



13.191E

Two pound moles of ammonia are burned in a steady state process with *x* lb mol of oxygen. The products, consisting of H_2O, N_2, and the excess O_2, exit at 400 F, 1000 lbf/in.^{2}.

a. Calculate *x* if half the water in the products is condensed.

b. Calculate the absolute entropy of the products at the exit conditions.

$$2NH_3 + xO_2 \rightarrow 3H_2O + N_2 + (x - 1.5)O_2$$

Products at 400 F, 1000 lbf/in^2 with $n_{H2O\ LIQ} = n_{H2O\ VAP} = 1.5$

$$a)\ y_{H2O\ VAP} = \frac{P_G}{P} = \frac{247.1}{1000} = \frac{1.5}{1.5 + 1 + x - 1.5}$$

$x =$ **5.070**

$$b)\ S_{PROD} = S_{GAS\ MIX} + S_{H2O\ LIQ}$$

Gas mixture:

	n_i	y_i	$\bar{s}_i^\circ$	$-\bar{R}\ln\frac{y_i P}{P_0}$	$\bar{S}_i$
H_2O	1.5	0.2471	48.939	-5.604	43.335
O_2	3.57	0.5881	52.366	-7.326	45.040
N_2	1.0	0.1648	49.049	-4.800	44.249

$$S_{GAS\ MIX} = 1.5(43.335) + 3.57(45.040) + 1.0(44.249) = 270.04\ \text{Btu/R}$$

$$S_{H2O\ LIQ} = 1.5[16.707 + 18.015(0.5647 - 0.0877)] = 37.95\ \text{Btu/R}$$

$S_{PROD} = 270.04 + 37.95 =$ **307.99 Btu/R**