# INSTITUTE OF ENGINEERING

# PULCHOWK CAMPUS

# DEPARTMENT OF MECHANICAL

# ENGINEERING

# FUNDAMENTALS OF THERMODYNAMICS AND HEAT TRANSFER

**[TUTORIAL SHEETS]**

**ELECTRICAL, ELECTRONICS & COMPUTER (I/II)**

**2070 Even Semester**

# CONTENTS

# FUNDAMENTALS OF THERMODYNAMICS AND HEAT TRANSFER

# TUTORIAL NO: 1

# THERMODYNAMIC PROPERTIES

1. A container has two compartments separated by a membrane as shown in **Figure P1.1**. Compartment A has 2 kg of air and a volume of 1 $m^3$; compartment B has 1.5 $m^3$ of air with a specific volume of 2.5 $m^3/kg$. If the membrane is broken, determine the resultant specific volume.

2. A cylinder with a total volume of 1 $m^3$ has a movable piston as shown in **Figure P1.3**. When the piston is at one fourth of the length, both sides have same specific volume of 4 $m^3/kg$. Determine the specific volumes of both sides when the piston is at middle of the cylinder.

3. An oxygen cylinder having a volume of 10 $m^3$ initially contains 5 kg of oxygen. Determine the specific volume of oxygen in the cylinder initially. During certain process 3 kg of oxygen is consumed, determine the final specific volume of oxygen in the cylinder. Also plot the amount of oxygen that has been consumed versus the specific volume of the remaining in the cylinder.

4. Three pressure gauges are connected to a container consisting of two compartments as shown in **Figure P1.4**. If the local barometer reads 750 mm of Hg and pressure gauges A and B read 300 kPa and 200 kPa respectively. Determine the absolute pressure in each compartment and reading of pressure gauge C. [Take $\rho_{HG}$ =13600 kg/m$^3$ and $g$ = 9.81 m/s$^2$]

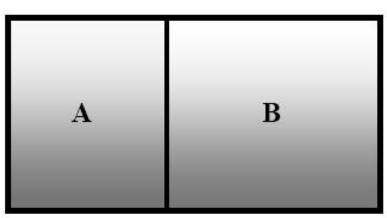



**Figure P1.1**

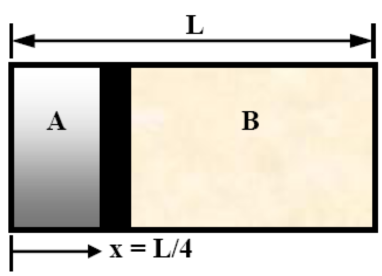



**Figure P1.2**

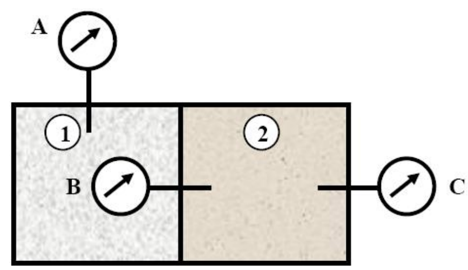
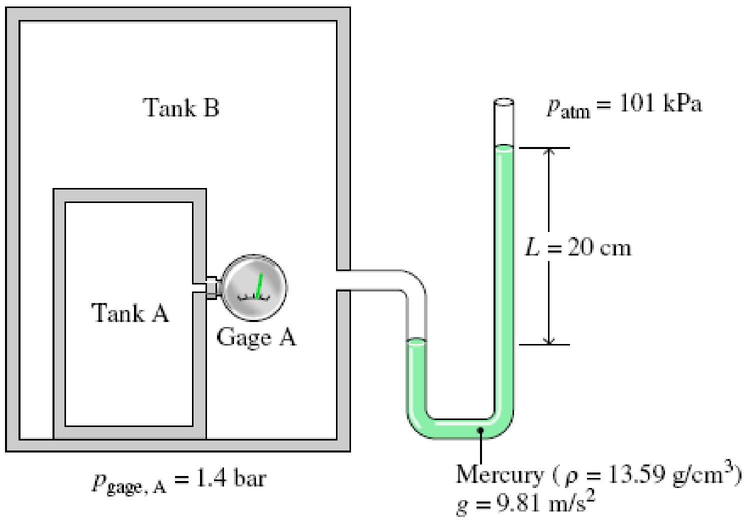



**Figure P1.4**

5. **Figure P1.5** shows a tank within a tank, each containing air. Pressure gage A is located inside the tank B and reads 140 kPa. The U-tube manometer connected to tank B contains mercury. Using data on the diagram, determine the absolute pressures inside the tank A and tank B.

6. A vertical piston–cylinder device shown in **Figure P1.6** contains a gas at a pressure of 100 kPa. The piston has a mass of 5 kg and a diameter of 12 cm. Pressure of the gas is to be increased by placing some weights on the piston. Determine the local atmospheric pressure and the mass of the weights that will double the pressure of the gas inside the cylinder. [Take $g = 9.81\ m/s^2$]

7. For the piston cylinder device shown in **Figure P1.7**, determine the force necessary to produce an absolute pressure of 500 kPa within the device. [Take $P_{atm} = 100\ kPa$]



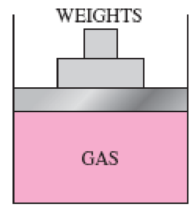




**Figure P1.6**

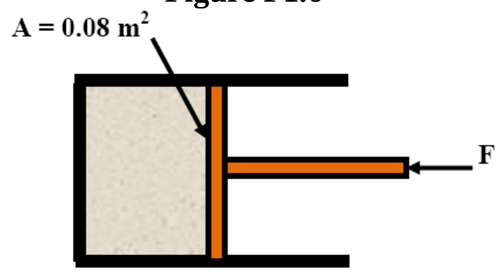
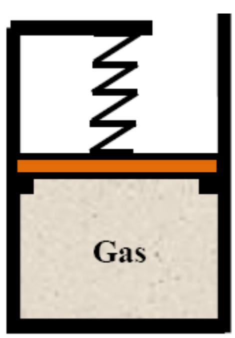



**Figure P1.5** **Figure P1.7**

**8.** A piston cylinder device loaded with a linear spring with a spring constant of k = 100 kN/m contains a gas initially at a pressure of 100 kPa and a volume of 0.05 m$^3$, as shown in **Figure P1.8**. The cross sectional area of the piston is 0.1 m$^2$. Initially spring touches the piston but exerts no force on it. Heat is supplied to the system until its volume doubles, determine the final pressure.

**9.** A 5 kg piston in a cylinder with diameter of 100 mm is loaded with a linear spring and the outside atmospheric pressure of 100 kPa. The spring exerts no force on the piston when it is at the bottom of the cylinder and for the state shown in **Figure P1.9**, the pressure is 400 kPa with volume of 0.4 L. The valve is opened to let some air in, causing the piston to rise 2 cm. Find the new pressure. [Take $g = 9.81\ m/s^2$].



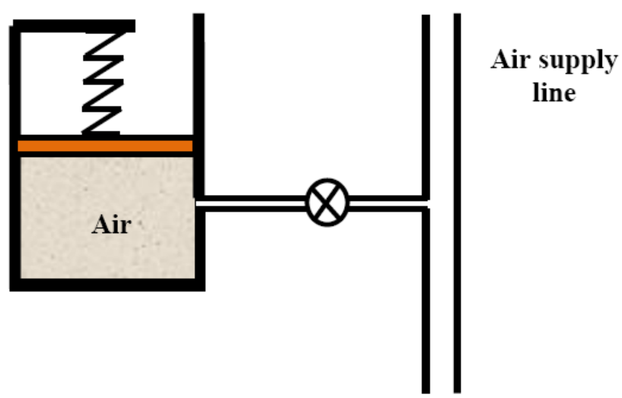




**Figure P1.8** **Figure P1.9**

**10.** A new scale N of temperature is deviced in such a way that the freezing point of ice is 100$^0$N and boiling point is 400$^0$N. What is the temperature reading on this new scale when the temperature is 150$^0$C? At what temperature, both the Celsius and new temperature scale reading would be the same?

## ANSWERS

| | | | | | |
|---|---|---|---|---|---|
| **1.** | $0.96154\ \mathrm{m^3/kg}$ | **2.** | $8\ \mathrm{m^3/kg}$, $2.667\ \mathrm{m^3/kg}$ | **3.** | $2\ \mathrm{m^3/kg}$, $5\ \mathrm{m^3/kg}$ |
| **4.** | $400.062\ kPa$, $600.062\ kPa$, $500kPa$ | | | **5.** | 127.67 kPa, 267.67 kPa |
| **6.** | $95.7\ kPa$, $115.3\ kg$ | **7.** | $32\ kN$ | **8.** | $600\ kPa$ |
| **9.** | $515.36\ kPa$ | **10.** | $550\ {}^{0}N, -50$ | | |

# FUNDAMENTALS OF THERMODYNAMICS AND HEAT TRANSFER

# TUTORIAL NO: 2

# ENERGY TRANSFER

**1.** A mass of gas is compressed in a quasi-static process from 80 kPa, 0.1 $m^3$ to 0.4 MPa, 0.03 $m^3$. Assuming that the pressure and volume are related by $PV^n$ = *constant*, find the work done by the gas system.

**2.** Air is compressed in a cylinder form 1 $m^3$ to 0.35 $m^3$ by a piston. The relation between the pressure and volume is given by $P = 5 - 3V$, where P is in bar and V is in $m^3$. Compute the magnitude of the work done on the system in kJ.

**3.** In a quasiequilibrium process in a closed system, a gas expands from a volume of 0.15 $m^3$ and a pressure of 120 kPa to a volume of 0.25 $m^3$ in such a manner that P (V + 0.030) = constant, where V is in $m^3$. Calculate the work.

**4.** An ideal gas undergoes two processes in series

**Process 1-2:** an expansion from 0.1 $m^3$ to 0.2 $m^3$ at constant pressure of 200 kPa
**Process 2-3:** an expansion from 0.2 $m^3$ to 0.4 $m^3$ with a linear rising pressure from 200 kPa to 400 kPa.

Sketch the process on P-V diagram and determine the total work transfer.

**5.** Air undergoes three process in series to from a cycle:
**Process 1-2:** compression with PV = constant form $P_1$ = 100 kPa, $V_1$ = 0.1 $m^3$ to $P_1$ = 500 kPa
**Process 2-3:** constant volume process to $P_3 = P_1$
**Process 3-1:** constant pressure

Sketch the process on P-V diagram and determine the total work transfer.

**6.** A piston cylinder device shown in **Figure P2.6** contains 0.1 kg of air initially at a pressure of 4 MPa and temperature of $200^0$C. Heat is added to the system until the pressure is 8 MPa and the temperature is $800^0$C. Sketch the process on P-V and T-V diagrams and determine the total work transfer. [Take *R = 287 J/kg K*]

**7.** Air (0.5 kg) in the piston cylinder device shown in **Figure P2.7** has an initial pressure and temperature of 1 MPa and $500^0$C respectively. The system is cooled until the temperature reaches $50^0$C. It takes a pressure of 0.5 MPa to support the piston. Sketch the process on P-V and T-V diagrams and determine the total work transfer. [Take *R = 287 J/kg K*]

**8.** An unstretched spring ($k = 1\ kN/m$) is attached to a piston cylinder device as shown in **Figure P2.8**. Heat is added until the gas pressure inside the cylinder is 400 kPa. If the diameter of the piston is 50 mm, determine the work done by the gas on the piston. [Take $P_{atm} = 100\ kPa$]

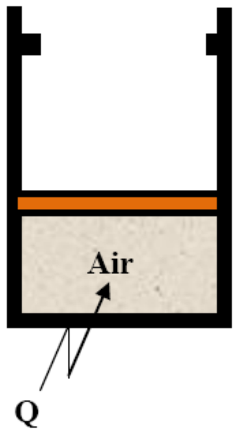



Figure P2.6


Figure P2.7


Figure P2.8

**9.** A piston cylinder arrangement with two set of stops is restrained by a linear spring ($k = 12\ kN/m$) as shown in **Figure P2.9**. The cross sectional area of the piston is 0.05 $m^2$.The initial pressure of the gas is 500 kPa and the pressure required to lift the piston is 1000 kPa. Heat is supplied to the gas until its pressure reaches 6000 kPa. Sketch the process on P-V diagram and determine the total work transfer.

**10.** Air (0.01 kg) is contained in a piston cylinder device restrained by a linear spring ($k = 500\ kN/m$) as shown in **Figure P2.10**. Spring initially touches the piston but exerts no force on it. Heat is added to the system until the piston is displaced upward by 80 mm. determine
**(a)** the temperature at which piston leaves the stops
**(b)** work done by the air [Take $R = 287$ *J/kg. K*, $P_{atm} = 100\ kPa$ and $g = 9.81\ m/s^2$]

**11.** A gas enclosed by a piston shown in **Figure P2.11** starts to expand due to heating. The initial movement of 0.2 m is restrained by a fixed mass of 30 kg and the final 0.05 m is restrained both by the mass and a spring of stiffness 10 kN/m. The cross sectional area of the piston is 0.15 $m^2$ and the atmospheric pressure is 100 kPa.
- **(a)** Neglecting the mass of the spring and the piston sketch a P-V diagram of the process.
- **(b)** Calculate the work during the initial 0.2 m movement.
- **(c)** Calculate the total work done.

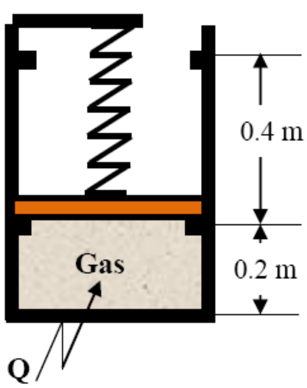



Figure P2.9

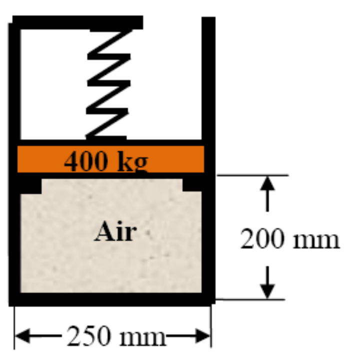



Figure P2.10

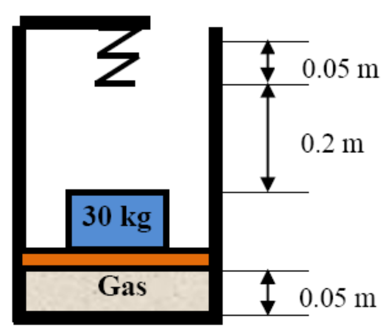



Figure P2.11

**12.** A piston cylinder arrangement shown in **Figure P2.12** is restrained by two linear springs as shown. The system contains air initially at a pressure of 150 kPa and a volume of 0.002 $m^3$. Heat is added to the system until its volume doubles; determine the total work transfer. Also sketch the process on P-V diagram. Both springs have spring constant of 100 kN/m.

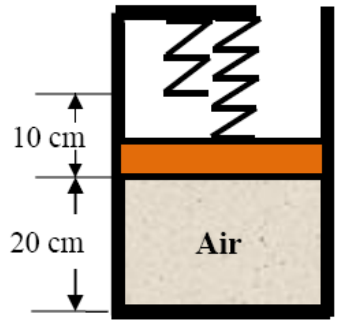



**Figure P2.12**

## ANSWERS

| | | | | | |
|---|---|---|---|---|---|
| **1.** | $-11.83\ kJ$ | **2.** | $-193.375\ kJ$ | **3.** | $9.54\ kJ$ |
| **4.** | $80\ kJ$ | **5.** | $-8.09\ kJ$ | **6.** | $1.82\ kJ$ |
| **7.** | $-9.112\ kJ$ | **8.** | 0.28915 kJ | **9.** | $2.96\ kJ$ |
| **10.** | $342.52^0C$, $2.31\ kJ$ | **11.** | $3.06\ kJ$, $3.84\ kJ$ | **12.** | $2.8\ kJ$ |

# FUNDAMENTALS OF THERMODYNAMICS AND HEAT TRANSFER

# TUTORIAL NO: 3

# PROPERIES OF COMMON SUBSTANCES

**1.** Fill in the blanks in the following table with the corresponding properties of water or by the symbol ×, when it is no relevant or meaningless or by the symbol ─, when it is indeterminate.

| State | P, kPa | T, $^0$C | x, % | v, m$^3$/kg | h, kJ/kg | Degree of Superheat |
|---|---|---|---|---|---|---|
| **1** | 200 | 200 | | | | |
| **2** | 250 | | 80 | | | |
| **3** | 300 | | | 0.5 | | |
| **4** | | 150 | 60 | | | |
| **5** | | 200 | | 0.1 | | |
| **6** | | 250 | | 0.5951 | | |
| **7** | 1000 | | | | 2000 | |
| **8** | | 350 | | | 2563.5 | |
| **9** | 600 | | | 0.001101 | | |
| **10** | 2000 | | | 0.1757 | | |
| **11** | 5000 | | | 0.001206 | | |
| **12** | | 500 | | | 3445.4 | |
| **13** | 8000 | 295.04 | | | | |

**2.** A two phase mixture of $H_2O$ has a temperature of $200^0$C and occupies a volume of 0.05 m$^3$. The mass of saturated liquid is 1 kg and saturated vapor is 3 kg. Determine the pressure and specific volume of the mixture.

**3.** Determine the temperature and quality (if needed) for water at a pressure of 200 kPa and having a specific volume of
**(a)** 0.8 m$^3$/kg
**(b)** 1.25 m$^3$/kg.

**4.** Water is contained in a rigid vessel of 5 m$^3$ at a quality of 0.8 and a pressure of 2 MPa. If it is cooled to a pressure of 400 kPa, determine the mass of saturated liquid and saturated vapor at the final state.

**5.** A piston cylinder device shown in **Figure P3.5** contains 0.2 kg of a mixture of saturated liquid water and saturated water vapor at a temperature of $50^0$C and a volume of 0.03 m$^3$. The mass of the piston resting on the stops is 50 kg and the cross sectional area of the piston is 12.2625 cm$^2$. The atmospheric pressure is 100 kPa. Heat is transferred until it becomes saturated vapor. Sketch the process on P-v and T-v diagrams and determine:
**(a)** the temperature at which the piston just leaves the stops,
**(b)** the final pressure, and
**(c)** the total work transfer. [Take g = 9.81 ms$^{-2}$]

**6.** A piston cylinder device shown in **Figure P3.6** contains water initially at a pressure of 125 kPa with a quality of 50 %. Heat is added to the system until it reaches to a final temperature

of 800$^0$C. It takes a pressure of 600 kPa to lift the piston from the stops. Sketch the process on P-v and T-v diagrams and determine:
**(a)** the mass of $H_2O$ in the system, and
**(b)** the total work transfer.

7. The frictionless piston shown in **Figure P3.7** has a mass of 20 kg and a cross sectional area of 78.48 cm$^2$. Heat is added until the temperature reaches 400$^0$C. If the quality of the $H_2O$ at the initial state is 0.2, determine:
**(a)** the initial pressure,
**(b)** the mass of $H_2O$,
**(c)** the quality of the system when the piston hits the stops,
**(d)** the final pressure, and
**(e)** the total work transfer. [Take $P_{atm}$ = 100 kPa, g = 9.81 m/s$^2$]

8. Water (2 kg) is contained within a piston-cylinder arrangement as shown in **Figure P3.8**. The initial temperature is 105$^0$C, and there are equal masses of liquid and vapor initially. The system is heated to a position where the piston is locked, and then the system is cooled to the saturated vapor state at T = 50$^0$C. Draw the process on a P-v diagram, and evaluate the work done during the process.

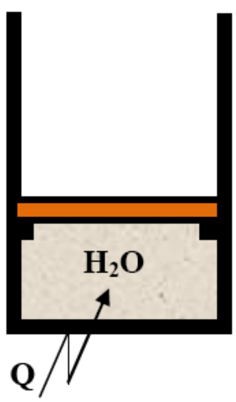


**Figure P3.5**

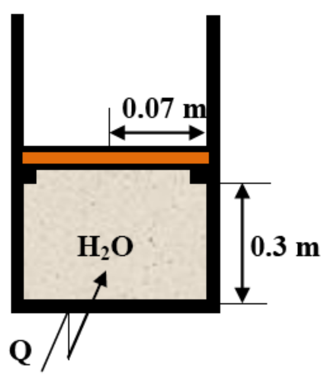


**Figure P3.6**

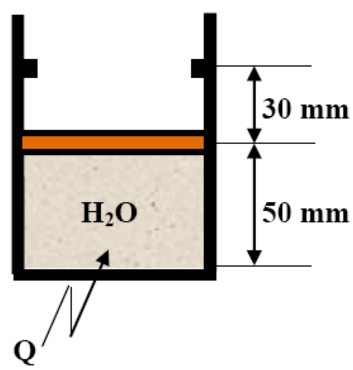


**Figure P3.7**

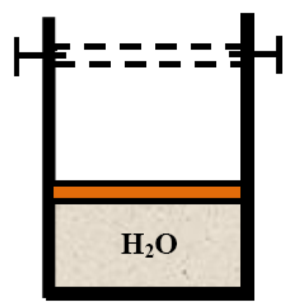


**Figure P3.8**

9. A piston cylinder arrangement shown in **Figure P3.9** contains 1 kg of water initially at a pressure of 1 MPa and a temperature of 500$^0$C. The water is cooled until it is completely converted into the saturated liquid. It requires a pressure of 400 kPa to support the piston. Sketch the process on P-v and T-v diagrams and determine the total work transfer.

10. A piston cylinder arrangement shown in **Figure P3.10** contains 2 kg of water initially at a pressure of 200 kPa and a temperature of 50$^0$C. Heat is added until the piston reaches the upper stops where the total volume is 1.5 m$^3$. It takes a pressure of 600 kPa to lift the piston. Sketch the process on P-v and T-v diagrams and determine the final temperature and the work transfer.

11. A piston cylinder device with a linear spring initially contains water at a pressure of 4 MPa and 500$^0$C with the initial volume being 0.1 m$^3$, as shown in **Figure P3.11**. If the piston is at the bottom, the system pressure is 300 kPa. The system now cools until the pressure reaches 1000 kPa. Sketch the process on P-v diagram and determine
**(a)** the mass of $H_2O$

**(b)** the final temperature and volume, and
**(c)** the total work transfer.

**12.** A piston cylinder arrangement shown in **Figure P3.12** contains water initially at $P_1$ = 100 kPa, $x_1$ = 0.8 and $V_1$ = 0.01 $m^3$. When the system is heated, it encounters a linear spring (k = 100 kN/m). At this state volume is 0.015 $m^3$. The heating continues till its pressure is 200 kPa. If the diameter of the piston is 0.15 m, determine
**(a)** the final temperature, and
**(b)** the total work transfer.
Also sketch the process on P-v diagram.

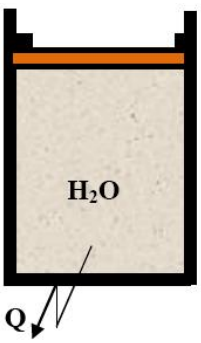



**Figure P3.9**

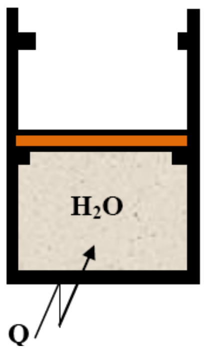



**Figure P3.10**

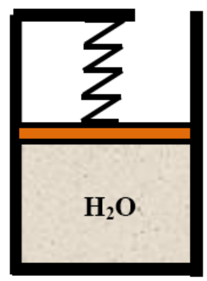



**Figure P3.11**

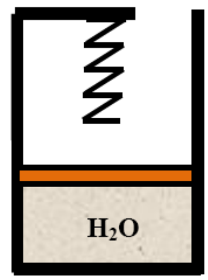



**Figure P3.12**

## ANSWERS

**1.**

| State | P, kPa | T, $^0$C | x, % | v, $m^3$/kg | h, kJ/kg | Degree of Superheat, $^0$C |
|---|---|---|---|---|---|---|
| 1 | 200 | 200 | × | **1.0803** | **2870.0** | **79.76** |
| 2 | 250 | **127.44** | 80 | **0.575227** | **2280.53** | × |
| 3 | 300 | **133.56** | **82.495** | 0.5 | **2346.544** | × |
| 4 | **475.72** | 150 | 60 | **0.23617** | **1900.78** | × |
| 5 | **1553.6** | 200 | **78.385** | 0.1 | **2373.135** | × |
| 6 | **400** | 250 | × | 0.5951 | **2963.6** | **106.36** |
| 7 | 1000 | **179.92** | **61.402** | **0.11982** | 2000 | × |
| 8 | **16520** | 350 | **100** | **0.008812** | 2563.5 | **0** |
| 9 | 600 | **158.86** | **0** | 0.001101 | **670.71** | × |
| 10 | 2000 | **500** | × | 0.1757 | **3467.7** | **287.58** |
| 11 | 5000 | **230** | × | 0.001206 | **990.43** | × |
| 12 | **4000** | 500 | × | **0.08642** | 3445.4 | **249.61** |
| 13 | 8000 | 295.04 | — | — | — | — |

**2.** 1553.6 kPa, 0.095731 $m^3$/kg
**3.** 120.24$^0$C,0.90296; 271.806$^0$C
**4.** 10.6896 kg, 51.8847 kg
**5.** 151.87$^0$C, 500 kPa, 22.49 kJ
**6.** 0.006714 kg, 0.5497 kJ
**7.** 125 kPa, 0.0014 kg, 0.321,711.71 kPa, 0.0294 kg
**8.** 2736.24 kJ
**9.** – 141.2 kJ
**10.** 703.618$^0$C, 898.785 kJ
**11.** 1.1571 kg; 179.92$^0$C, 0.01892 $m^3$; – 202.703 kJ
**12.** 627.165$^0$C, 0.54684 kJ

# FUNDAMENTALS OF THERMODYNAMICS AND HEAT TRANSFER

## TUTORIAL NO: 4

## FIRST LAW OF THERMODYNAMICS

1. A gas contained in a piston cylinder device undergoes a polytropic process for which pressure volume relationship is given by $PV^{2.5} = constant$. The initial pressure is $400\ kPa$, the initial volume is $0.2\ m^3$ and the final volume is $0.4\ m^3$. The internal energy of the gas decreases by $20\ kJ$ during the process. Determine the work transfer and heat transfer for the process.
2. A closed rigid tank contains $2\ kg$ of a saturated water vapor initially at $160^0C$. Heat transfer occurs from the system and the pressure drops to $150\ kPa$. Determine the amount of heat lost by the system.
3. A piston cylinder device shown in **Figure P4.3** loaded with a linear spring ($k = 20\ kN/m$) contains $0.5\ kg$ of $H_2O$ initially at a pressure of $200\ kPa$ and a volume of $0.4\ m^3$. Heat is transferred to the $H_2O$ until a final pressure of $400\ kPa$ is reached. If the cross sectional area of the piston is $0.05\ m^2$, determine the final temperature and the heat transfer for the process.
4. Nitrogen ($5\ kg$) is contained in a piston cylinder device shown in **Figure P4.4** initially at a pressure of $800\ kPa$ and a temperature of $127^0C$. There is a heat transfer to the system until the temperature reaches to $527^0C$ . It takes a pressure of $1500\ kPa$ to lift the piston. Sketch the process on $P - V$ and $T - V$ diagrams and determine the total work and heat transfer in the process. [Take $R = 297\ J/kgK$ and $c_V = 743\ J/kgK$].
5. Air is contained in a piston cylinder device shown in **Figure P4.5** initially at a pressure and temperature of $1000\ kPa$ and $800^0C$. Heat is lost by the system until its pressure drops to $750\ kPa$. Sketch the process on $P - V$ and $T - V$ diagrams and determine the total work and heat transfer. [Take $R = 287\ J/kgK$ and $c_V = 718\ J/kgK$]

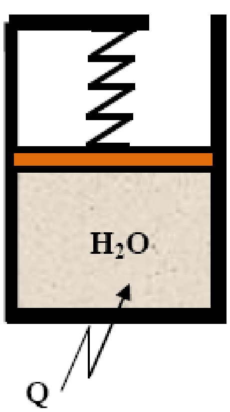



**Figure P4.3**

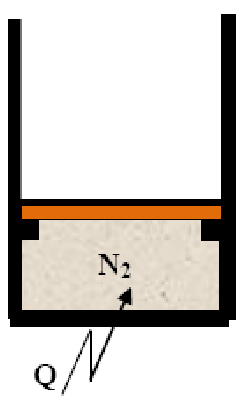



**Figure P4.4**

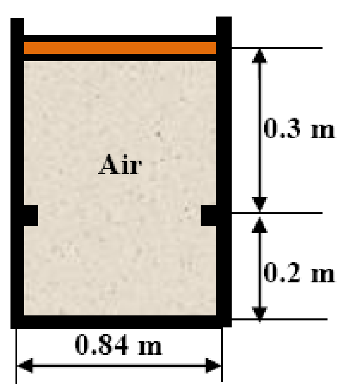



**Figure P4.5**

6. Air ($0.1\ kg$) is contained in piston/cylinder assembly as shown in **Figure P4.6**. Initially, the piston rests on the stops and is in contact with the spring, which is in its unstretched position. The spring constant is $100\ kN/m$. The piston weighs $30\ kN$ and atmospheric pressure is

$101\ kPa$. The air is initially at $300\ K$ and $200\ kPa$. Heat transfer occurs until the air temperature reaches the surrounding temperature of $700\ K$.
**(a)** Find the final pressure and volume.
**(b)** Find the process work.
**(c)** Find the heat transfer.
**(d)** Draw the P-V diagram of the process. [Take $R = 287\ J/kgK$ and $c_V = 718\ J/kgK$].

**7.** Water ($0.5\ kg$) is contained in a piston cylinder device shown in **Figure P4.7** initially at a pressure of $200\ kPa$ with a quality of $80\ \%$. Mass of the piston is such that a pressure of $300\ kPa$ is required to lift it. Heat is transferred to the system until its volume doubles. Sketch the process on $P - v$ and $T - v$ diagrams and determine
**(a)** the final temperature
**(b)** the total work transfer, and
**(c)** the total work transfer.

**8.** A piston cylinder device shown in **Figure P4.8** contains $4\ kg$ of water initially at saturated liquid state at $5\ MPa$. There is a heat transfer to the system until it hits the stops at which time its volume is $0.08\ m^3$. There is further heat transfer to the device until water is completely vaporized. Sketch the process on $P - v$ and $T - v$ diagrams and determine the total work and heat transfer.

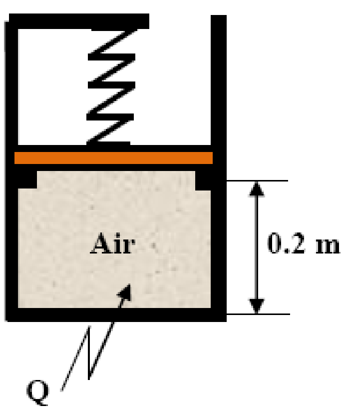



**Figure P4.6**

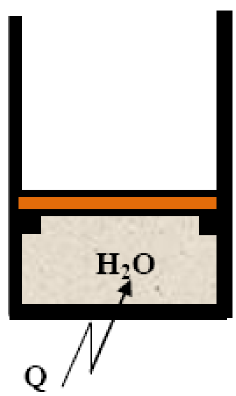



**Figure P4.7**

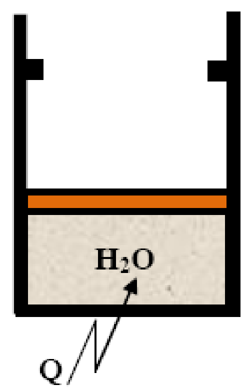



**Figure P4.8**

**9.** A piston cylinder device shown in **Figure P4.9** contains water initially at $P_1 = 1\ MPa$ and $T_1 = 500^0C$. A pressure of 400 kPa is required to support the piston. There is a heat transfer from the device until its temperature drops to $30^0C$. Sketch the process on $P - v$ and $T - v$ diagrams and determine the total work and heat transfer.

**10.** A closed system undergoes a process $A$ from state 1 to state 2 as shown in **Figure P4.10**; which requires a heat input of $Q_A = 65\ kJ$. The system returns adiabatically from state 2 to state 1 through process $B$. Determine the work transfer for process $B$.

**11.** Steam enters a turbine operating at steady state with a mass flow rate of $1.2\ kg/s$. Properties of the steam at the inlet are $P_1 = 5\ MPa$, $T_1 = 450^0C$ $\bar{V}_1 = 10\ m/s$ and at the exit are $P_2 = 100\ kPa$, $x_2 = 80\ \%$ $\bar{V}_2 = 50\ m/s$. If the power output of the turbine is $1200\ kW$, determine the rate of heat transfer from the turbine.

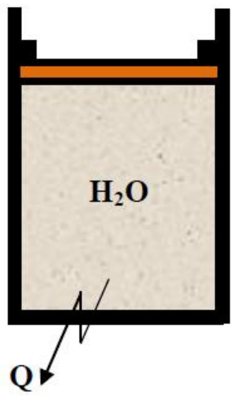



Figure P4.9

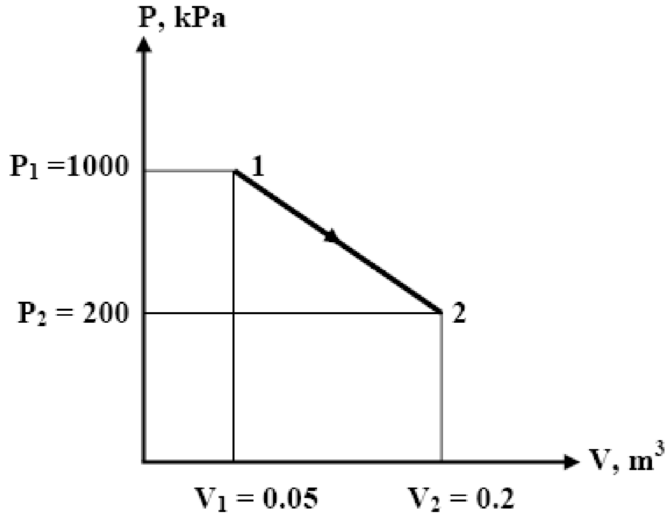



Figure P4.10

**12.** Air expands through an adiabatic turbine from $1000\ kPa$, $1000\ K$ to $100\ kPa$, $400\ K$. The inlet velocity is $10\ m/s$ whereas exit velocity is $100\ m/s$. The power output of the turbine is $3600\ kW$. Determine the mass flow rate of air and the inlet and exit areas. [Take $R = 287\ J/kgK$ and $c_P = 1005\ J/kgK$].

**13.** Steam enters an adiabatic nozzle with $P_1 = 2.5\ MPa$, $T_1 = 250^0C$ and with very low velocity. The steam exits the nozzle with $P_2 = 0.8\ MPa$ and velocity of $65\ m/s$. The mass flow rate of steam is $2\ kg/s$. Determine the exit area of the nozzle.

**14.** A water heating arrangement operates at steady state with liquid water entering at inlet 1 with $P_1 = 500\ kPa$ and $T_1 = 50^0C$. Steam at $P_2 = 500\ kPa$ and $T_2 = 200^0C$ enters at inlet 2. Saturated liquid water exits with a pressure of $P_3 = 500\ kPa$ from the outlet 3. Determine the ratio of mass flow rates $\dot{m}_1/\dot{m}_2$.

**15.** Steam enters into a well insulated throttling valve at $10\ MPa$, $600^0C$ and exits at $5\ MPa$. Determine the final temperature of the steam.

**ANSWERS**

| | | | | | |
|---|---|---|---|---|---|
| **1.** | 34.477 kJ, 14.477 kJ | **2.** | $-3118.08\ kJ$ | **3.** | 466.209$^0$C, 377.5495 kJ |
| **4.** | 74.25 kJ, 1560.25 kJ | **5.** | −166.32 kJ, −651.76 kJ | | |
| **6.** | 294.63 kPa, 0.0682 m$^3$, 6.72 kJ, 35.44 kJ | | | **7.** | 87.7152 kJ, 1531.3152 kJ |
| **7.** | 649.48$^0$C, 106.335 kJ, 738.214 kJ | | | | |
| **8.** | 374.28 kJ, 6002.98 kJ | **9.** | −176.55 kJ, −3175.38 kJ | **10.** | – 25 kJ |
| **11.** | −109.812 kW | **12.** | 6.019 kg/s, 0.1728 m$^2$, 0.0691 m$^2$ | | |
| **13.** | 7.0339 × 10$^{-4}$ m$^2$ | **14.** | 5.1375 | **15.** | 582.112$^0$C |

## FUNDAMENTALS OF THERMODYNAMICS AND HEAT TRANSFER

# TUTORIAL NO: 5

# SECOND LAW OF THERMODYNAMICS

**1.** An inventor makes the following claims. Determine whether the claims are valid and explain why or why not.

**(a)** A refrigeration unit maintains – $10^0$C in the refrigerator which is kept in a room where the surrounding temperature is $25^0$C and has a COP of 8.5.

**(b)** A building receives a heat transfer 50000 kJ/h from a heat pump. The inside temperature is maintained at $22^0$C, and the surroundings are at – $1^0$C. The inventor claims a work input of 7000 kJ/h is required.

**(c)** An engineer claims his engine to develop 3.75 kW. On testing, the engine consumes 0.44 kg of fuel per hour having a calorific value of 42000 kJ/kg. The maximum temperature recorded in the cycle is $1400^0$C and minimum is $350^0$C.

**2.** A heat pump cycle operating between two reservoirs takes energy from the source at $T_L = 270\ K$ and supplies $Q_H$ to a room at $T_H = 300\ K$. For each of the following case, determine whether the cycle operates reversibly, irreversibly or impossible.

**(a)** $Q_H = 1000 kJ$, $W = 200\ kJ$

**(b)** $Q_H = 2000 kJ$, $Q_L = 1800\ kJ$

**(c)** $W = 200\ kJ$, $Q_L = 2000\ kJ$

**(d)** $COP = 8.6$

**3.** A car engine having a thermal efficiency of $40\ \%$ produces $40\ kW$ of power output. Determine the fuel consumption rate in $kg/h$, if the calorific value of the fuel is $42000\ kJ/kg$.

**4.** The difference between source and sink temperatures of an ideal heat engine is $450^0 C$. If the work output of the engine is 1.5 the heat rejected, determine its thermal efficiency, source temperature and sink temperature.

**5.** A heat pump maintains a room at a temperature of $20^0 C$ when the surroundings is at $5^0 C$. The rate of heat loss from the room is estimated to be $0.6\ kW$ per degree temperature difference between the inside and outside. If the electricity costs $Rs\ 10/kWh$, determine the minimum theoretical cost per day.

**6.** An air conditioning unit having a COP $50\ \%$ of the theoretical maximum maintains a house at a temperature of $20^0 C$ by cooling it against the surroundings temperature. The house gains energy at a rate of $0.8\ kW$ per degree temperature difference. For a maximum work input of $1.8\ kW$, determine the maximum surroundings temperature for which it provides sufficient cooling.

**7.** Water is contained in a piston cylinder device with two set of stops as shown in **Figure P5.7** is initially at $1\ MPa$ and $400^0 C$. The limiting volumes are $V_{min} = 1\ m^3$ and $V_{max} = 2\ m^3$. The weight of the piston is such that a pressure of $400\ kPa$ is required to support the piston. The system is cooled to $100^0 C$ by allowing system to reject heat to the surroundings at

$25^0C$. Sketch the process on $P-v$ and $T-v$ diagrams and determine the total entropy generated during the process.

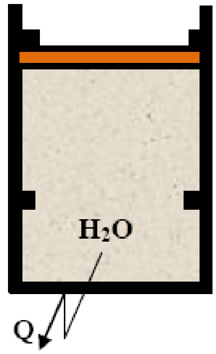



**Figure P5.7**

**8.** Two kg of water at $90^0$C is mixed with three kg of water at $10^0$C in an isolated system. Calculate the change of entropy due to the mixing process. [$C_P$ *for water = 4.18 kJ/kg K*]

**9.** A lump of steel ($c_S = 0.5\ kJ/kgK$) of mass $10\ kg$ at $727^0C$ is dropped in $100\ kg$ of oil ($c_O = 3.5\ kJ/kgK$) at $27^0C$. Determine the net change in entropy.

**10.** $1\ kg$ of air enclosed in an isolated box with volume $V_1$, pressure $P_1$ and temperature $T_1$ is allowed to expand freely until its volume increases to $V_2 = 2V_1$. Determine the change in entropy. [Take $R = 287\ J/kgK$]

**11.** Steam enters a nozzle at $1.5\ MPa$ and $300^0C$ and with a velocity of $50\ m/s$, undergoes a reversible adiabatic process and exits at $200\ kPa$. Determine the exit velocity.

**12.** Air at $100\ kPa$ and $25^0C$ enters into a diffuser at a velocity of $150\ m/s$ and exits with a velocity $40\ m/s$. Assuming the process to be reversible and adiabatic, determine the exit pressure and temperature of the air.

**13.** Steam enters into a well insulated throttling valve at $10\ MPa$ and $600^0C$ and exits at $5\ MPa$. Determine the change in entropy per unit mass of the steam.

**14.** Steam enters an adiabatic turbine at $5\ MPa$ ,$500^0C$ and with a velocity of $50\ m/s$ and exits at $50\ kPa$, $100^0C$ and with a velocity of $150\ m/s$. If the power output of the turbine is $50\ MW$, determine
**(a)** the mass flow rate of steam flowing through the turbine, and
**(b)** the isentropic efficiency of the turbine..

**15.** Air enters a gas turbine at $1\ MPa$ and $1500\ K$ and exits at $100\ kPa$. If its isentropic efficiency is 80 %, determine the turbine exit temperature.

## ANSWERS

| | | | | | |
|---|---|---|---|---|---|
| **1.** | Invalid, Valid, Invalid | **2.** | Irreversible, reversible, impossible, irreversible | | |
| **3.** | 8.57 kg/h | **4.** | 60 %, 750 K, 300 K | **5.** | Rs 11.58 |
| **6.** | $38.156^0$C | **7.** | 18.18056 kJ/K | **8.** | 1.025 kJ/K |
| **9.** | 5.4592 kJ/K | **10.** | 198.93 J/K | **11.** | 910.405 m/s |
| **12.** | 308.39 K, 112.75 kPa | **13.** | 0.3075 kJ/kg K | **14.** | 6.74036 kg/s, 73.65 % |
| **15.** | 921.537 K | | | | |

# FUNDAMENTALS OF THERMODYNAMICS AND HEAT TRANSFER

# TUTORIAL NO: 6

# THERMODYNAMIC CYCLES

**1.** Air at the compressor inlet of an ideal gas turbine cycle is at $100\ kPa$ and $20^0C$. The heat added to the cycle per kg of air is $800\ kJ/kg$. The maximum temperature during the cycle is limited to $1400\ K$. Determine
**(a)** the pressure ratio,
**(b)** the net work output per kg of air, and
**(a)** the cycle efficiency.

**2.** In an ideal Brayton cycle, air enters the compressor at $100\ kPa$ and $300\ K$ and the turbine at $1000\ kPa$ and $1200\ K$. Heat is transferred to the air at a rate of $30\ MW$. Determine the efficiency and the power output of the plant.

**3.** The compressor and turbine of an ideal gas turbine each have isentropic efficiencies of $80\ \%$. The pressure ratio is $10$. The minimum and maximum temperatures are $300\ K$ and $1500\ K$ respectively. Determine:
**(a)** the net work per kg of air,
**(b)** the thermal efficiency of the cycle, and
**(c)** Compare both of these for a cycle with ideal compressor and turbine.

**4.** The compression ratio of an ideal Otto cycle is $8.5$. At the beginning of the compression stroke, air is at $100\ kPa$ and $27^0C$. The pressure is doubled during the constant volume heat addition process. Determine:
**(a)** the heat added per kg of air,
**(b)** the net work output per kg of air,
**(c)** the thermal efficiency, and
**(d)** the mean effective pressure..

**5.** The following data are obtained for a four stroke petrol engine:

| | |
|---|---|
| Cylinder bore | $= 14\ cm$ |
| Stroke length | $= 15\ cm$ |
| Clearance volume | $= 231\ cm^3$ |

Determine:
**(a)** the ratio of clearance volume and swept volume,
**(b)** the compression ratio, and
**(c)** the thermal efficiency.

**6.** An engine with bore of $8\ cm$ and stroke of $12\ cm$ has a compression ratio of $6$. To increase the compression ratio $1.5\ mm$ is machined off the cylinder head face. Determine the new compression ratio.

**7.** The properties of air at the beginning of compression stroke in an air standard Diesel cycle are $100\ kPa$ and $300\ K$. The air at the beginning of the expansion stroke is at $6500\ kPa$ and $2000\ K$. Determine:

**(a)** the compression ratio,
**(b)** the thermal efficiency, and
**(c)** the mean effective pressure.

**8.** An air standard diesel cycle has a compression ratio of $22$ and expansion ratio of $11$. Determine its cut off ratio and the efficiency.

**9.** Air at the beginning of compression stroke in an ideal Diesel cycle is at $100\ kPa$ and $295\ K$ and the compression ratio is $20$. Determine the maximum temperature during the cycle to have an efficiency of $65$ %.

**10.** A Rankine cycle has a boiler working at a pressure of $2\ MPa$. The maximum and minimum temperatures during the cycle are $400^0C$ and $50^0C$ respectively. Determine the efficiency of the cycle and compare it with that of the Carnot cycle operating between the same temperature limits.

**11.** Saturated vapor enters into a turbine of an ideal Rankine cycle at $10\ MPa$ and saturated liquid exits the condenser at $10\ kPa$. The power output of the cycle is $120\ MW$. Determine:
**(a)** the thermal efficiency of the cycle,
**(b)** the back work ratio,
**(c)** the mass flow rate of steam,
**(d)** the rate at which heat is supplied to the boiler,
**(e)** the rate at which heat is rejected from the condenser, and
**(f)** the mass flow rate of condenser cooling water, if the cooling water enters at $20^0C$ and exits at $35^0C$. [Take specific heat of water as $4.18\ kJ/kgK$]..

**12.** Superheated steam at $8\ MPa$, $500^0C$ enters into turbine of a steam power plant working on a Rankine cycle. The steam leaves the condenser as saturated liquid at $8\ kPa$. The turbine and pump have isentropic efficiencies of $90$ % and $80$ % respectively. For the cycle, determine:
**(a)** the net work per kg of steam,
**(b)** the heat supplied into the boiler per kg of steam, and
**(c)** the thermal efficiency.

## ANSWERS

**1.** 12.58, 411.91 kJ/kg, 51.49 %
**2.** 48.205 %, 14.46 MW
**3.** 230.599 kJ/kg, 26.96 %; 446.089 kJ/kg, 48.205 %
**4.** 507.01 kJ/kg, 291.61 kJ/kg, 57.52 %, 383.84 kPa
**5.** 0.1, 11, 61.68 %
**6.** 6.41
**7.** 19.72, 64.38 %, 800.47 kPa
**8.** 2, 65.99 %
**9.** 1886 K
**10.** 31.635 %, 52.01 %
**11.** 37.22 %, 1.063 %, 127.8 kg/s, 322.38 MW, 202.38 MW, 3227.82 kg/s
**12.** 1155.54 kJ/kg, 3214.58 kJ/kg, 35.95 %

# FUNDAMENTALS OF THERMODYNAMICS AND HEAT TRANSFER

# TUTORIAL NO: 7

# HEAT TRANSFER

1. A hollow cylinder with inner and outer diameters of $8\ cm$ and $12\ cm$ respectively has an inner surface temperature of $200^0C$ and an outer surface temperature of $50^0C$. If the thermal conductivity of the cylinder material is $60\ W/mK$, determine the heat transfer from the unit length of the pipe. Also determine the temperature at the surface at a radial distance of $10\ cm$ from the axis of the cylinder.

2. The roof of an electrically heated home is $10\ m$ long, $8\ m$ wide, and $0.25\ m$ thick, and is made of a flat layer of concrete whose thermal conductivity is $k = 0.8\ W/mK$. The temperatures of the inner and the outer surfaces of the roof one night are measured to be $18^0C$ and $5^0C$, respectively, for a period of $12\ hours$. Determine:
   **(a)** the rate of heat loss through the roof that night and
   **(b)** the cost of that heat loss to the home owner if the cost of electricity is $Rs\ 10/kWh$.

3. The heat flux at the surface of an electrical heater is $3500\ W/m^2$. The heater surface temperature is $120^0C$ when it is cooled by air at $50^0C$. What is the average convective heat transfer coefficient? What will the heater temperature be if the power is reduced so that heat flux is $2500\ W/m^2$?

4. A room is maintained at $22^0C$ by an air conditioning unit. Determine the total rate of heat transfer from the person standing in the room if the exposed surface area and the average outer surface temperature of the person are $1.5\ m^2$ and $30^0C$, respectively, and the convection heat transfer coefficient is $10\ W/m^2K$. Take surface emissivity as $0.95$.

5. A flat plate collector is insulated at the back surface and exposed to solar radiation at the front surface. The front surface receives solar radiation at a rate of $850\ W/m^2$ and dissipates heat to the ambient air at $20^0C$ both by convection and radiation. If the convection heat transfer coefficient between the plate and air is $16\ W/m^2K$, determine the surface temperature of the plate.

6. The inner surface of a $2\ cm$ thick $50\ cm \times 50\ cm$ plate ($k = 10\ W/mK$) is at $400^0C$. The outer surface dissipates heat by combined convection and radiation to the ambient air at $27^0C$. If the plate surface has an emissivity $0.85$ of and the convection heat transfer coefficient between the outer plate surface and the ambient air is $20\ W/m^2K$, determine the outer surface temperature of the plate.

7. A furnace is made of fireclay brick of thickness $0.3\ m$ and thermal conductivity of $1.2\ W/mK$. The outside surface is to be insulated by an insulating material with the thermal conductivity of $0.05\ W/mK$. Determine the thickness of the insulating layer in order to limit the heat loss per unit area of the furnace wall to $1200\ W/m^2$ when the inside surface of the wall is at $900^0C$ and the outside surface is at $25^0C$.

**8.** Find the heat transfer through the composite wall as shown in **Figure P7.8**. Assume one dimensional flow. The thermal conductivities of wall materials are $k_A = 150\,W/mK$, $k_B = 30\,W/mK$, $k_C = 65\,W/mK$ and $k_D = 50\,W/mK$. All dimensions are in $cm$.

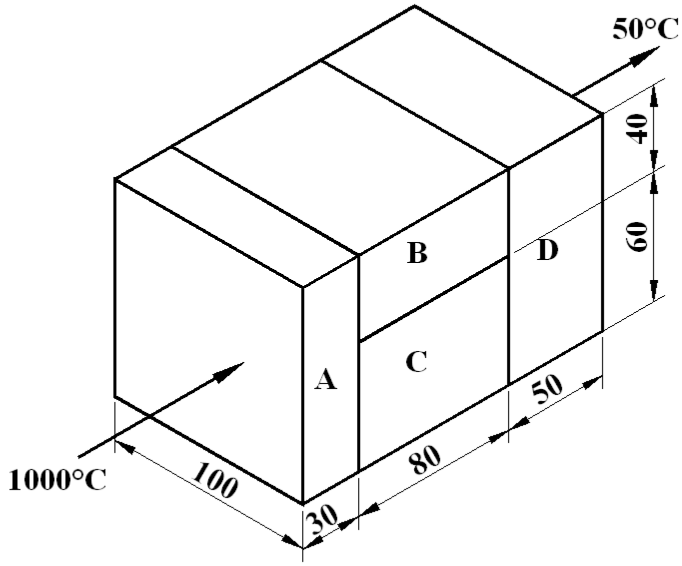



**Figure P7.8**

**9.** A composite wall consists of 12 $cm$ thick layer of common brick of thermal conductivity 0.8 $W/mK$ and 4 $cm$ thick plaster of thermal conductivity 0.5 $W/mK$.An insulating material of thermal conductivity 0.1 $W/mK$ is to be added to reduce the heat transfer through wall by 75 %. Determine the required thickness of the insulating layer.

**10.** A 200 mm diameter 50 m long pipe carrying steam is covered with 40 mm of high temperature insulation ($k = 0.1$ W/m) and 30 mm of low temperature insulation ($k = 0.05$ W/m). The inner and outer surfaces of the insulating layers are at $400^0C$ and $40^0C$ respectively. Determine:
**(a)** the rate of heat loss from the pipe,
**(b)** the temperature at the interface of two insulating layers,
**(c)** the rate of heat transfer from unit area of the pipe surface, and
**(d)** the rate of heat transfer from unit area of the outer surface of the composite insulation.

**11.** A gas turbine blade is modeled as a flat plate. The thermal conductivity of the blade material is 15 $W/mK$ and its thickness is 1.5 $mm$. The upper surface of the blade is exposed to hot gases at $1000^0C$ and the lower surface is cooled by air bled of the compressor. The heat transfer coefficients at the upper and lower surfaces of the blade are $2500\,W/m^2K$ and $1500\,W/m^2K$ respectively. Under steady state conditions, the temperature, at the upper surface of the blade is measured as $850^0C$, determine the temperature of the coolant air.

**12.** A 2 $m$ long steel plate ($k = 50\,W/mK$) is well insulated on its sides, while its left section is maintained at $100^0C$ and the right section is exposed to ambient air at $20^0C$. Under steady state conditions, a thermocouple inserted at the middle of the plate gives a temperature of $80^0C$. Determine the value of convection heat transfer coefficient for convection heat transfer between the right section of the plate and air.

## ANSWERS

**1.** 139.47 kW/m, $117.45^0$C
**2.** 3.328 kW, Rs 399.36
**3.** 50 W/$m^2$/K, $100^0$C
**4.** 189.126 W
**5.** 332.4067K
**6.** 613.51K
**7.** 2.396 cm
**8.** 34.313 kW
**9.** 6.9 cm
**10.** 15604.3 W, $232.87^0$C, 494.69 W/$m^2$, 292.18 W/$m^2$
**11.** $562.5^0$C
**12.** 25 W/$m^2$K

# APPENDIX 2

## Table A2.1: Properties of SATURATED WATER – Pressure Table

| P kPa | T $^0$C | $v_l$ $m^3$/kg | $v_{lg}$ $m^3$/kg | $v_g$ $m^3$/kg | $u_l$ kJ/kg | $u_{lg}$ kJ/kg | $u_g$ kJ/kg | $h_l$ kJ/kg | $h_{lg}$ kJ/kg | $h_g$ kJ/kg | $s_l$ kJ/kg.K | $s_{lg}$ kJ/kg.K | $s_g$ kJ/kg.K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.0 | 6.9696 | 0.001 | 129.19 | 129.19 | 29.287 | 2354.8 | 2384.1 | 29.288 | 2484.0 | 2513.3 | 0.1059 | 8.8678 | 8.9737 |
| 1.5 | 13.021 | 0.001001 | 87.970 | 87.971 | 54.634 | 2337.9 | 2392.5 | 54.635 | 2469.8 | 2524.4 | 0.1954 | 8.6304 | 8.8258 |
| 2.0 | 17.497 | 0.001001 | 66.997 | 66.998 | 73.364 | 2325.2 | 2398.6 | 73.366 | 2459.2 | 2532.6 | 0.2603 | 8.4613 | 8.7216 |
| 2.5 | 21.080 | 0.001002 | 54.248 | 54.249 | 88.353 | 2315.1 | 2403.5 | 88.356 | 2450.7 | 2539.1 | 0.3116 | 8.3295 | 8.6411 |
| 3.0 | 24.083 | 0.001003 | 45.660 | 45.661 | 100.92 | 2306.7 | 2407.6 | 100.92 | 2443.7 | 2544.6 | 0.3541 | 8.2214 | 8.5755 |
| 3.5 | 26.677 | 0.001003 | 39.473 | 39.474 | 111.77 | 2299.4 | 2411.2 | 111.77 | 2437.5 | 2549.3 | 0.3904 | 8.1299 | 8.5203 |
| 4.0 | 28.966 | 0.001004 | 34.797 | 34.798 | 121.34 | 2293.0 | 2414.3 | 121.35 | 2432.2 | 2553.5 | 0.4222 | 8.0503 | 8.4725 |
| 4.5 | 31.018 | 0.001005 | 31.136 | 31.137 | 129.93 | 2287.2 | 2417.1 | 129.93 | 2427.3 | 2557.2 | 0.4506 | 7.9799 | 8.4305 |
| 5.0 | 32.881 | 0.001005 | 28.190 | 28.191 | 137.72 | 2281.9 | 2419.6 | 137.72 | 2422.8 | 2560.5 | 0.4761 | 7.9169 | 8.3930 |
| 5.5 | 34.589 | 0.001006 | 25.767 | 25.768 | 144.86 | 2277.0 | 2421.9 | 144.87 | 2418.7 | 2563.6 | 0.4994 | 7.8598 | 8.3592 |
| 6.0 | 36.167 | 0.001006 | 23.737 | 23.738 | 151.46 | 2272.5 | 2424.0 | 151.47 | 2415.0 | 2566.5 | 0.5208 | 7.8075 | 8.3283 |
| 6.5 | 37.635 | 0.001007 | 22.013 | 22.014 | 157.60 | 2268.4 | 2426.0 | 157.61 | 2411.5 | 2569.1 | 0.5406 | 7.7594 | 8.3000 |
| 7.0 | 39.008 | 0.001008 | 20.528 | 20.529 | 163.35 | 2264.5 | 2427.9 | 163.35 | 2408.3 | 2571.6 | 0.5590 | 7.7148 | 8.2738 |
| 7.5 | 40.299 | 0.001008 | 19.236 | 19.237 | 168.75 | 2260.9 | 2429.6 | 168.76 | 2405.1 | 2573.9 | 0.5763 | 7.6731 | 8.2494 |
| 8.0 | 41.518 | 0.001008 | 18.102 | 18.103 | 173.85 | 2257.5 | 2431.3 | 173.85 | 2402.3 | 2576.1 | 0.5925 | 7.6342 | 8.2267 |
| 8.5 | 42.673 | 0.001009 | 17.098 | 17.099 | 178.68 | 2254.1 | 2432.8 | 178.68 | 2399.4 | 2578.1 | 0.6078 | 7.5975 | 8.2053 |
| 9.0 | 43.771 | 0.001009 | 16.202 | 16.203 | 183.27 | 2251.0 | 2434.3 | 183.27 | 2396.8 | 2580.1 | 0.6223 | 7.5629 | 8.1852 |
| 9.5 | 44.817 | 0.001010 | 15.398 | 15.399 | 187.64 | 2248.1 | 2435.7 | 187.65 | 2394.4 | 2582.0 | 0.6361 | 7.5301 | 8.1662 |
| 10 | 45.817 | 0.001010 | 14.673 | 14.674 | 191.82 | 2245.2 | 2437.0 | 191.83 | 2392.0 | 2583.8 | 0.6493 | 7.4989 | 8.1482 |
| 15 | 53.983 | 0.001014 | 10.022 | 10.023 | 225.97 | 2221.9 | 2447.9 | 225.98 | 2372.2 | 2598.2 | 0.7550 | 7.2516 | 8.0066 |
| 20 | 60.073 | 0.001017 | 7.6489 | 7.6499 | 251.44 | 2204.5 | 2455.9 | 251.46 | 2357.4 | 2608.9 | 0.8321 | 7.0747 | 7.9068 |
| 25 | 64.980 | 0.001020 | 6.2038 | 6.2048 | 271.97 | 2190.3 | 2462.3 | 271.99 | 2345.4 | 2617.4 | 0.8933 | 6.9365 | 7.8298 |
| 30 | 69.114 | 0.001022 | 5.2288 | 5.2298 | 289.27 | 2178.4 | 2467.7 | 289.30 | 2335.3 | 2624.6 | 0.9441 | 6.8231 | 7.7672 |
| 35 | 72.700 | 0.001024 | 4.5252 | 4.5262 | 304.28 | 2168.0 | 2472.3 | 304.32 | 2326.4 | 2630.7 | 0.9878 | 6.7266 | 7.7144 |
| 40 | 75.877 | 0.001026 | 3.9930 | 3.9940 | 317.59 | 2158.8 | 2476.4 | 317.64 | 2318.5 | 2636.1 | 1.0261 | 6.6427 | 7.6688 |
| 45 | 78.736 | 0.001028 | 3.5759 | 3.5769 | 329.58 | 2150.4 | 2480.0 | 329.62 | 2311.3 | 2640.9 | 1.0603 | 6.5684 | 7.6287 |
| 50 | 81.339 | 0.001030 | 3.2398 | 3.2408 | 340.49 | 2142.8 | 2483.3 | 340.54 | 2304.8 | 2645.3 | 1.0912 | 6.5016 | 7.5928 |
| 60 | 85.949 | 0.001033 | 2.7314 | 2.7324 | 359.84 | 2129.2 | 2489.0 | 359.90 | 2293.1 | 2653.0 | 1.1454 | 6.3856 | 7.5310 |
| 70 | 89.956 | 0.001036 | 2.3644 | 2.3654 | 376.68 | 2117.3 | 2494.0 | 376.75 | 2282.9 | 2659.6 | 1.1920 | 6.2869 | 7.4789 |
| 80 | 93.511 | 0.001038 | 2.0866 | 2.0876 | 391.63 | 2106.7 | 2498.3 | 391.71 | 2273.6 | 2665.3 | 1.2330 | 6.2009 | 7.4339 |
| 90 | 96.713 | 0.001041 | 1.8688 | 1.8698 | 405.11 | 2097.1 | 2502.2 | 405.20 | 2265.3 | 2670.5 | 1.2696 | 6.1247 | 7.3943 |
| 100 | 99.632 | 0.001043 | 1.6933 | 1.6943 | 417.41 | 2088.3 | 2505.7 | 417.51 | 2257.6 | 2675.1 | 1.3027 | 6.0562 | 7.3589 |
| 101.32 | 100.00 | 0.001043 | 1.6727 | 1.6737 | 418.96 | 2087.1 | 2506.1 | 419.06 | 2256.6 | 2675.7 | 1.3069 | 6.0476 | 7.3545 |
| 125 | 105.99 | 0.001048 | 1.3742 | 1.3752 | 444.25 | 2068.9 | 2513.2 | 444.38 | 2240.7 | 2685.1 | 1.3741 | 5.9100 | 7.2841 |
| 150 | 111.38 | 0.001053 | 1.1584 | 1.1595 | 467.02 | 2052.4 | 2519.4 | 467.18 | 2226.2 | 2693.4 | 1.4338 | 5.7894 | 7.2232 |
| 175 | 116.07 | 0.001057 | 1.0027 | 1.0038 | 486.89 | 2037.8 | 2524.7 | 487.08 | 2213.3 | 2700.4 | 1.4851 | 5.6866 | 7.1717 |
| 200 | 120.24 | 0.001060 | 0.8848 | 0.8859 | 504.59 | 2024.8 | 2529.4 | 504.80 | 2201.7 | 2706.5 | 1.5304 | 5.5968 | 7.1272 |
| 225 | 124.01 | 0.001064 | 0.7923 | 0.7934 | 520.59 | 2012.9 | 2533.5 | 520.83 | 2191.2 | 2712.0 | 1.5708 | 5.5172 | 7.0880 |
| 250 | 127.44 | 0.001067 | 0.7177 | 0.7188 | 535.22 | 2001.9 | 2537.1 | 535.49 | 2181.3 | 2716.8 | 1.6075 | 5.4454 | 7.0529 |
| 275 | 130.61 | 0.001070 | 0.6563 | 0.6574 | 548.73 | 1991.8 | 2540.5 | 549.02 | 2172.3 | 2721.3 | 1.6411 | 5.3800 | 7.0211 |

## TABLE A2.1: Properties of SATURATED WATER – Pressure Table (Continued)

| P kPa | T $^0$C | $v_l$ m$^3$/kg | $v_{lg}$ m$^3$/kg | $v_g$ m$^3$/kg | $u_l$ kJ/kg | $u_{lg}$ kJ/kg | $u_g$ kJ/kg | $h_l$ kJ/kg | $h_{lg}$ kJ/kg | $h_g$ kJ/kg | $s_l$ kJ/kg.K | $s_{lg}$ kJ/kg.K | $s_g$ kJ/kg.K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | 133.56 | 0.001073 | 0.6048 | 0.6059 | 561.29 | 1982.2 | 2543.5 | 561.61 | 2163.7 | 2725.3 | 1.6721 | 5.3200 | 6.9921 |
| 325 | 136.31 | 0.001076 | 0.5609 | 0.5620 | 573.04 | 1973.3 | 2546.3 | 573.39 | 2155.6 | 2729.0 | 1.7009 | 5.2645 | 6.9654 |
| 350 | 138.89 | 0.001079 | 0.5232 | 0.5243 | 584.10 | 1964.8 | 2548.9 | 584.48 | 2147.9 | 2732.4 | 1.7278 | 5.2129 | 6.9407 |
| 375 | 141.33 | 0.001081 | 0.4903 | 0.4914 | 594.56 | 1956.7 | 2551.3 | 594.96 | 2140.6 | 2735.6 | 1.7531 | 5.1646 | 6.9177 |
| 400 | 143.64 | 0.001084 | 0.4614 | 0.4625 | 604.47 | 1949.0 | 2553.5 | 604.91 | 2133.6 | 2738.5 | 1.7770 | 5.1191 | 6.8961 |
| 425 | 145.84 | 0.001086 | 0.4357 | 0.4368 | 613.91 | 1941.7 | 2555.6 | 614.37 | 2126.9 | 2741.3 | 1.7996 | 5.0762 | 6.8758 |
| 450 | 147.94 | 0.001088 | 0.4129 | 0.4140 | 622.93 | 1934.7 | 2557.6 | 623.42 | 2120.5 | 2743.9 | 1.8211 | 5.0356 | 6.8567 |
| 475 | 149.94 | 0.001090 | 0.3923 | 0.3934 | 631.56 | 1927.8 | 2559.4 | 632.07 | 2114.2 | 2746.3 | 1.8415 | 4.9971 | 6.8386 |
| 500 | 151.87 | 0.001093 | 0.3738 | 0.3749 | 639.84 | 1921.4 | 2561.2 | 640.38 | 2108.2 | 2748.6 | 1.8610 | 4.9604 | 6.8214 |
| 550 | 155.49 | 0.001097 | 0.3415 | 0.3426 | 655.48 | 1908.9 | 2564.4 | 656.08 | 2096.8 | 2752.9 | 1.8977 | 4.8917 | 6.7894 |
| 600 | 158.86 | 0.001101 | 0.3145 | 0.31560 | 670.05 | 1897.3 | 2567.3 | 670.71 | 2086.0 | 2756.7 | 1.9315 | 4.8286 | 6.7601 |
| 650 | 162.02 | 0.001104 | 0.2915 | 0.2926 | 683.71 | 1886.2 | 2569.9 | 684.42 | 2075.8 | 2760.2 | 1.9631 | 4.7699 | 6.7330 |
| 700 | 164.98 | 0.001108 | 0.2717 | 0.2728 | 696.58 | 1875.8 | 2572.4 | 697.35 | 2066.0 | 2763.3 | 1.9925 | 4.7154 | 6.7079 |
| 750 | 167.79 | 0.001111 | 0.2544 | 0.2555 | 708.76 | 1865.8 | 2574.6 | 709.59 | 2056.6 | 2766.2 | 2.0203 | 4.6642 | 6.6845 |
| 800 | 170.44 | 0.001115 | 0.2393 | 0.2404 | 720.33 | 1856.3 | 2576.6 | 721.23 | 2047.7 | 2768.9 | 2.0464 | 4.6161 | 6.6625 |
| 850 | 172.97 | 0.001118 | 0.2258 | 0.2269 | 731.37 | 1847.1 | 2578.5 | 732.32 | 2039.1 | 2771.4 | 2.0712 | 4.5706 | 6.6418 |
| 900 | 175.39 | 0.001121 | 0.2138 | 0.2149 | 741.92 | 1838.3 | 2580.2 | 742.93 | 2030.7 | 2773.6 | 2.0948 | 4.5274 | 6.6222 |
| 950 | 177.70 | 0.001124 | 0.2030 | 0.2041 | 752.03 | 1829.8 | 2581.8 | 753.10 | 2022.6 | 2775.7 | 2.1173 | 4.4863 | 6.6036 |
| 1000 | 179.92 | 0.001127 | 0.1933 | 0.1944 | 761.75 | 1821.6 | 2583.3 | 762.88 | 2014.8 | 2777.7 | 2.1388 | 4.4471 | 6.5859 |
| 1100 | 184.10 | 0.001133 | 0.1764 | 0.1775 | 780.14 | 1805.9 | 2586.0 | 781.38 | 1999.8 | 2781.2 | 2.1793 | 4.3736 | 6.5529 |
| 1200 | 188.00 | 0.001138 | 0.1622 | 0.1633 | 797.31 | 1791.1 | 2588.4 | 798.68 | 1985.6 | 2784.3 | 2.2167 | 4.3059 | 6.5226 |
| 1300 | 191.64 | 0.001144 | 0.1501 | 0.1512 | 813.44 | 1777.1 | 2590.5 | 814.93 | 1972.1 | 2787.0 | 2.2515 | 4.2430 | 6.4945 |
| 1400 | 195.08 | 0.001149 | 0.1397 | 0.1408 | 828.67 | 1763.6 | 2592.3 | 830.28 | 1959.1 | 2789.4 | 2.2842 | 4.1841 | 6.4683 |
| 1500 | 198.33 | 0.001154 | 0.1305 | 0.1317 | 843.12 | 1750.8 | 2593.9 | 844.85 | 1946.7 | 2791.5 | 2.3150 | 4.1288 | 6.4438 |
| 1600 | 201.41 | 0.001159 | 0.1225 | 0.1237 | 856.88 | 1738.4 | 2595.3 | 858.73 | 1934.6 | 2793.3 | 2.3441 | 4.0766 | 6.4207 |
| 1700 | 204.35 | 0.001163 | 0.1155 | 0.1167 | 870.02 | 1726.6 | 2596.6 | 872.00 | 1923.0 | 2795.0 | 2.3717 | 4.0272 | 6.3989 |
| 1800 | 207.15 | 0.001168 | 0.1092 | 0.1104 | 882.61 | 1715.1 | 2597.7 | 884.71 | 1911.7 | 2796.4 | 2.3980 | 3.9801 | 6.3781 |
| 1900 | 209.84 | 0.001172 | 0.1035 | 0.1047 | 894.70 | 1704.0 | 2598.7 | 896.92 | 1900.7 | 2797.6 | 2.4231 | 3.9353 | 6.3584 |
| 2000 | 212.42 | 0.001177 | 0.09841 | 0.09959 | 906.33 | 1693.2 | 2599.5 | 908.69 | 1890.0 | 2798.7 | 2.4471 | 3.8925 | 6.3396 |
| 2250 | 218.45 | 0.001187 | 0.08753 | 0.08872 | 933.70 | 1667.5 | 2601.2 | 936.37 | 1864.4 | 2800.8 | 2.5032 | 3.7926 | 6.2958 |
| 2500 | 223.99 | 0.001197 | 0.07875 | 0.07995 | 958.98 | 1643.3 | 2602.3 | 961.97 | 1840.2 | 2802.2 | 2.5544 | 3.7016 | 6.2560 |
| 2750 | 229.11 | 0.001207 | 0.07151 | 0.07272 | 982.53 | 1620.5 | 2603.0 | 985.85 | 1817.2 | 2803.0 | 2.6016 | 3.6178 | 6.2194 |
| 3000 | 233.89 | 0.001217 | 0.06544 | 0.06666 | 1004.6 | 1598.7 | 2603.3 | 1008.3 | 1795.0 | 2803.3 | 2.6454 | 3.5401 | 6.1855 |
| 3250 | 238.37 | 0.001226 | 0.06027 | 0.06150 | 1025.5 | 1577.7 | 2603.2 | 1029.5 | 1773.6 | 2803.1 | 2.6865 | 3.4673 | 6.1538 |
| 3500 | 242.60 | 0.001235 | 0.05582 | 0.05705 | 1045.3 | 1557.6 | 2602.9 | 1049.6 | 1753.0 | 2802.6 | 2.7251 | 3.3989 | 6.1240 |
| 3750 | 246.59 | 0.001244 | 0.05194 | 0.05318 | 1064.2 | 1538.1 | 2602.3 | 1068.8 | 1732.9 | 2801.7 | 2.7616 | 3.3341 | 6.0957 |
| 4000 | 250.39 | 0.001252 | 0.04852 | 0.04977 | 1082.2 | 1519.3 | 2601.5 | 1087.2 | 1713.4 | 2800.6 | 2.7962 | 3.2727 | 6.0689 |
| 5000 | 263.98 | 0.001286 | 0.03815 | 0.03944 | 1147.8 | 1448.7 | 2596.5 | 1154.2 | 1639.5 | 2793.7 | 2.9201 | 3.0524 | 5.9725 |
| 6000 | 275.62 | 0.001319 | 0.03112 | 0.03244 | 1205.4 | 1383.9 | 2589.3 | 1213.3 | 1570.6 | 2783.9 | 3.0266 | 2.8620 | 5.8886 |
| 7000 | 285.86 | 0.001352 | 0.02602 | 0.02737 | 1257.5 | 1322.7 | 2580.2 | 1267.0 | 1504.8 | 2771.8 | 3.1211 | 2.6919 | 5.8130 |

## TABLE A2.1: Properties of SATURATED WATER – Pressure Table (Continued)

| P kPa | T $^0$C | $v_l$ m$^3$/kg | $v_{lg}$ m$^3$/kg | $v_g$ m$^3$/kg | $u_l$ kJ/kg | $u_{lg}$ kJ/kg | $u_g$ kJ/kg | $h_l$ kJ/kg | $h_{lg}$ kJ/kg | $h_g$ kJ/kg | $s_l$ kJ/kg.K | $s_{lg}$ kJ/kg.K | $s_g$ kJ/kg.K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8000 | 295.04 | 0.001384 | 0.02214 | 0.02352 | 1305.5 | 1264.1 | 2569.6 | 1316.6 | 1441.2 | 2757.8 | 3.2066 | 2.5365 | 5.7431 |
| 9000 | 303.38 | 0.001418 | 0.01906 | 0.02048 | 1350.3 | 1207.3 | 2557.6 | 1363.1 | 1378.9 | 2742.0 | 3.2855 | 2.3916 | 5.6771 |
| 10,000 | 311.03 | 0.001452 | 0.01658 | 0.01803 | 1392.8 | 1151.4 | 2544.2 | 1407.3 | 1317.2 | 2724.5 | 3.3591 | 2.2548 | 5.6139 |
| 11,000 | 318.11 | 0.001488 | 0.01450 | 0.01599 | 1433.3 | 1096.2 | 2529.5 | 1449.7 | 1255.7 | 2705.4 | 3.4287 | 2.1238 | 5.5525 |
| 12,000 | 324.71 | 0.001526 | 0.01273 | 0.01426 | 1472.4 | 1041.0 | 2513.4 | 1490.7 | 1193.8 | 2684.5 | 3.4953 | 1.9968 | 5.4921 |
| 13,000 | 330.89 | 0.001566 | 0.01121 | 0.01278 | 1510.5 | 985.20 | 2495.7 | 1530.9 | 1130.9 | 2661.8 | 3.5595 | 1.8723 | 5.4318 |
| 14,000 | 336.70 | 0.001610 | 0.009870 | 0.01148 | 1547.9 | 928.40 | 2476.3 | 1570.4 | 1066.7 | 2637.1 | 3.6220 | 1.7491 | 5.3711 |
| 15,000 | 342.19 | 0.001657 | 0.008683 | 0.01034 | 1585.0 | 870.00 | 2455.0 | 1609.8 | 1000.3 | 2610.1 | 3.6837 | 1.6255 | 5.3092 |
| 16,000 | 347.39 | 0.001710 | 0.007600 | 0.009310 | 1622.1 | 809.20 | 2431.3 | 1649.5 | 930.80 | 2580.3 | 3.7452 | 1.4999 | 5.2451 |
| 17,000 | 352.34 | 0.001770 | 0.006603 | 0.008373 | 1659.9 | 744.90 | 2404.8 | 1690.0 | 857.10 | 2547.1 | 3.8073 | 1.3704 | 5.1777 |
| 18,000 | 357.04 | 0.001840 | 0.005665 | 0.007505 | 1698.9 | 675.70 | 2374.6 | 1732.0 | 777.70 | 2509.7 | 3.8714 | 1.2340 | 5.1054 |
| 19,000 | 361.52 | 0.001925 | 0.004756 | 0.006681 | 1740.3 | 599.00 | 2339.3 | 1776.8 | 689.40 | 2466.2 | 3.9393 | 1.0862 | 5.0255 |
| 20,000 | 365.80 | 0.002036 | 0.003838 | 0.005874 | 1786.0 | 510.10 | 2296.1 | 1826.7 | 586.90 | 2413.6 | 4.0146 | 0.9184 | 4.9330 |
| 21,000 | 369.88 | 0.002200 | 0.002820 | 0.005020 | 1841.4 | 396.00 | 2237.4 | 1887.6 | 455.20 | 2342.8 | 4.1062 | 0.7079 | 4.8141 |
| 22,000 | 373.77 | 0.002702 | 0.000952 | 0.003654 | 1953.4 | 142.80 | 2096.2 | 2012.8 | 163.60 | 2176.5 | 4.2866 | 0.2530 | 4.5486 |
| 22,055 | 373.98 | 0.00311 | - | 0.00311 | 2017 | - | 2017 | 2086 | - | 2086 | 4.409 | - | 4.409 |

## Table A2.2: Properties of SATURATED WATER – Temperature Table

| T $^0$C | P kPa | $v_l$ m$^3$/kg | $v_{lg}$ m$^3$/kg | $v_g$ m$^3$/kg | $u_l$ kJ/kg | $u_{lg}$ kJ/kg | $u_g$ kJ/kg | $h_l$ kJ/kg | $h_{lg}$ kJ/kg | $h_g$ kJ/kg | $s_l$ kJ/kg.K | $s_{lg}$ kJ/kg.K | $s_g$ kJ/kg.K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 0.8726 | 0.001000 | 147.02 | 147.02 | 21.020 | 2360.4 | 2381.4 | 21.021 | 2488.7 | 2509.7 | 0.07626 | 8.9473 | 9.0236 |
| 10 | 1.2281 | 0.001000 | 106.32 | 106.32 | 41.986 | 2346.3 | 2388.3 | 41.988 | 2476.9 | 2518.9 | 0.1510 | 8.7476 | 8.8986 |
| 15 | 1.7056 | 0.001001 | 77.896 | 77.897 | 62.915 | 2332.3 | 2395.2 | 62.917 | 2465.1 | 2528.0 | 0.2242 | 8.5550 | 8.7792 |
| 20 | 2.3388 | 0.001002 | 57.777 | 57.778 | 83.833 | 2318.2 | 2402.0 | 83.835 | 2453.4 | 2537.2 | 0.2962 | 8.3689 | 8.6651 |
| 25 | 3.1690 | 0.001003 | 43.356 | 43.357 | 104.75 | 2304.1 | 2408.9 | 104.75 | 2441.6 | 2546.3 | 0.3670 | 8.1888 | 8.5558 |
| 30 | 4.2455 | 0.001004 | 32.895 | 32.896 | 125.67 | 2290.0 | 2415.7 | 125.67 | 2429.6 | 2555.3 | 0.4365 | 8.0148 | 8.4513 |
| 35 | 5.6267 | 0.001006 | 25.219 | 25.220 | 146.58 | 2275.9 | 2422.5 | 146.59 | 2417.8 | 2564.4 | 0.5050 | 7.8461 | 8.3511 |
| 40 | 7.3814 | 0.001008 | 19.527 | 19.528 | 167.50 | 2261.7 | 2429.2 | 167.50 | 2405.9 | 2573.4 | 0.5723 | 7.6827 | 8.2550 |
| 45 | 9.5898 | 0.001010 | 15.262 | 15.263 | 188.41 | 2247.5 | 2435.9 | 188.42 | 2393.9 | 2582.3 | 0.6385 | 7.5244 | 8.1629 |
| 50 | 12.344 | 0.001012 | 12.036 | 12.037 | 209.31 | 2233.3 | 2442.6 | 209.33 | 2381.9 | 2591.2 | 0.7037 | 7.3708 | 8.0745 |
| 55 | 15.752 | 0.001015 | 9.5716 | 9.5726 | 230.22 | 2219.0 | 2449.2 | 230.24 | 2369.8 | 2600.0 | 0.7679 | 7.2217 | 7.9896 |
| 60 | 19.932 | 0.001017 | 7.6733 | 7.6743 | 251.13 | 2204.7 | 2455.8 | 251.15 | 2357.7 | 2608.8 | 0.8312 | 7.0768 | 7.9080 |
| 65 | 25.022 | 0.001020 | 6.1986 | 6.1996 | 272.05 | 2190.3 | 2462.4 | 272.08 | 2345.4 | 2617.5 | 0.8935 | 6.9360 | 7.8295 |
| 70 | 31.176 | 0.001023 | 5.0437 | 5.0447 | 292.98 | 2175.8 | 2468.8 | 293.01 | 2333.1 | 2626.1 | 0.9549 | 6.7991 | 7.7540 |
| 75 | 38.563 | 0.001026 | 4.1323 | 4.1333 | 313.92 | 2161.3 | 2475.2 | 313.96 | 2320.6 | 2634.6 | 1.0155 | 6.6658 | 7.6813 |
| 80 | 47.373 | 0.001029 | 3.4078 | 3.4088 | 334.88 | 2146.7 | 2481.6 | 334.93 | 2308.2 | 2643.1 | 1.0753 | 6.5359 | 7.6112 |
| 85 | 57.815 | 0.001032 | 2.8279 | 2.8289 | 355.86 | 2132.0 | 2487.9 | 355.92 | 2295.5 | 2651.4 | 1.1343 | 6.4093 | 7.5436 |
| 90 | 70.117 | 0.001036 | 2.3607 | 2.3617 | 376.86 | 2117.1 | 2494.0 | 376.93 | 2282.7 | 2659.6 | 1.1925 | 6.2859 | 7.4784 |
| 95 | 84.529 | 0.001040 | 1.9818 | 1.9828 | 397.89 | 2102.2 | 2500.1 | 397.98 | 2269.7 | 2667.7 | 1.2501 | 6.1653 | 7.4154 |
| 100 | 101.32 | 0.001043 | 1.6726 | 1.6736 | 418.96 | 2087.1 | 2506.1 | 419.06 | 2256.6 | 2675.7 | 1.3069 | 6.0476 | 7.3545 |
| 105 | 120.79 | 0.001047 | 1.4190 | 1.4200 | 440.05 | 2072.1 | 2512.1 | 440.18 | 2243.4 | 2683.6 | 1.3630 | 5.9326 | 7.2956 |
| 110 | 143.24 | 0.001052 | 1.2095 | 1.2106 | 461.19 | 2056.7 | 2517.9 | 461.34 | 2230.0 | 2691.3 | 1.4186 | 5.8200 | 7.2386 |
| 115 | 169.02 | 0.001056 | 1.0359 | 1.0370 | 482.36 | 2041.1 | 2523.5 | 482.54 | 2216.3 | 2698.8 | 1.4735 | 5.7098 | 7.1833 |
| 120 | 198.48 | 0.001060 | 0.8911 | 0.8922 | 503.57 | 2025.5 | 2529.1 | 503.78 | 2202.4 | 2706.2 | 1.5278 | 5.6019 | 7.1297 |
| 125 | 232.01 | 0.001065 | 0.7698 | 0.7709 | 524.82 | 2009.7 | 2534.5 | 525.07 | 2188.3 | 2713.4 | 1.5815 | 5.4962 | 7.0777 |
| 130 | 270.02 | 0.001070 | 0.6676 | 0.6687 | 546.12 | 1993.7 | 2539.8 | 546.41 | 2174.0 | 2720.4 | 1.6346 | 5.3926 | 7.0272 |
| 135 | 312.93 | 0.001075 | 0.5813 | 0.5824 | 567.46 | 1977.5 | 2545.0 | 567.80 | 2159.4 | 2727.2 | 1.6873 | 5.2907 | 6.9780 |
| 140 | 361.19 | 0.001080 | 0.5079 | 0.5090 | 588.85 | 1961.2 | 2550.0 | 589.24 | 2144.6 | 2733.8 | 1.7394 | 5.1908 | 6.9302 |
| 145 | 415.29 | 0.001085 | 0.4453 | 0.4464 | 610.30 | 1944.5 | 2554.8 | 610.75 | 2129.4 | 2740.2 | 1.7910 | 5.0926 | 6.8836 |
| 150 | 475.72 | 0.001090 | 0.3918 | 0.3929 | 631.80 | 1927.7 | 2559.5 | 632.32 | 2114.1 | 2746.4 | 1.8421 | 4.9960 | 6.8381 |
| 155 | 542.99 | 0.001096 | 0.3457 | 0.3468 | 653.35 | 1910.7 | 2564.0 | 653.95 | 2098.4 | 2752.3 | 1.8927 | 4.9010 | 6.7937 |
| 160 | 617.66 | 0.001102 | 0.3060 | 0.3071 | 674.97 | 1893.3 | 2568.3 | 675.65 | 2082.3 | 2758.0 | 1.9429 | 4.8074 | 6.7503 |
| 165 | 700.29 | 0.001108 | 0.2716 | 0.2727 | 696.65 | 1875.7 | 2572.4 | 697.43 | 2065.9 | 2763.3 | 1.9927 | 4.7151 | 6.7078 |
| 170 | 791.47 | 0.001114 | 0.2417 | 0.2428 | 718.40 | 1857.9 | 2576.3 | 719.28 | 2049.2 | 2768.5 | 2.0421 | 4.6241 | 6.6662 |
| 175 | 891.80 | 0.001121 | 0.2157 | 0.2168 | 740.22 | 1839.7 | 2579.9 | 741.22 | 2032.1 | 2773.3 | 2.0910 | 4.5344 | 6.6254 |
| 180 | 1001.9 | 0.001127 | 0.1929 | 0.1940 | 762.12 | 1821.3 | 2583.4 | 763.25 | 2014.6 | 2777.8 | 2.1397 | 4.4456 | 6.5853 |
| 185 | 1122.5 | 0.001134 | 0.1730 | 0.1741 | 784.10 | 1802.5 | 2586.6 | 785.37 | 1996.6 | 2782.0 | 2.1879 | 4.3580 | 6.5459 |
| 190 | 1254.2 | 0.001141 | 0.1554 | 0.1565 | 806.17 | 1783.4 | 2589.6 | 807.60 | 1978.2 | 2785.8 | 2.2358 | 4.2713 | 6.5071 |
| 195 | 1397.6 | 0.001149 | 0.1399 | 0.1410 | 828.33 | 1764.0 | 2592.3 | 829.93 | 1959.5 | 2789.4 | 2.2834 | 4.1855 | 6.4689 |
| 200 | 1553.6 | 0.001156 | 0.1261 | 0.1273 | 850.58 | 1744.1 | 2594.7 | 852.38 | 1940.1 | 2792.5 | 2.3308 | 4.1004 | 6.4312 |

# Table A2.2: Properties of SATURATED WATER – Temperature Table (Continued)

| T | P | $v_l$ | $v_{lg}$ | $v_g$ | $u_l$ | $u_{lg}$ | $u_g$ | $h_l$ | $h_{lg}$ | $h_g$ | $s_l$ | $s_{lg}$ | $s_g$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $^0$C | kPa | m$^3$/kg | m$^3$/kg | m$^3$/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg.K | kJ/kg.K | kJ/kg.K |
| 205 | 1722.9 | 0.001164 | 0.1140 | 0.1152 | 872.95 | 1723.9 | 2596.9 | 874.95 | 1920.4 | 2795.3 | 2.3778 | 4.0162 | 6.3940 |
| 210 | 1906.2 | 0.001173 | 0.1032 | 0.1044 | 895.43 | 1703.3 | 2598.7 | 897.66 | 1900.0 | 2797.7 | 2.4246 | 3.9326 | 6.3572 |
| 215 | 2104.2 | 0.001181 | 0.09357 | 0.09475 | 918.02 | 1682.3 | 2600.3 | 920.51 | 1879.2 | 2799.7 | 2.4712 | 3.8496 | 6.3208 |
| 220 | 2317.8 | 0.001190 | 0.08497 | 0.08616 | 940.75 | 1660.9 | 2601.6 | 943.51 | 1857.8 | 2801.3 | 2.5175 | 3.7672 | 6.2847 |
| 225 | 2547.9 | 0.001199 | 0.07726 | 0.07846 | 963.61 | 1638.9 | 2602.5 | 966.67 | 1835.7 | 2802.4 | 2.5637 | 3.6851 | 6.2488 |
| 230 | 2795.1 | 0.001209 | 0.07034 | 0.07155 | 986.62 | 1616.5 | 2603.1 | 990.00 | 1813.1 | 2803.1 | 2.6097 | 3.6034 | 6.2131 |
| 235 | 3060.4 | 0.001219 | 0.06412 | 0.06534 | 1009.8 | 1593.5 | 2603.3 | 1013.5 | 1789.8 | 2803.3 | 2.6556 | 3.5221 | 6.1777 |
| 240 | 3344.7 | 0.001229 | 0.05851 | 0.05974 | 1033.1 | 1570.0 | 2603.1 | 1037.2 | 1765.8 | 2803.0 | 2.7013 | 3.4410 | 6.1423 |
| 245 | 3648.8 | 0.001240 | 0.05345 | 0.05469 | 1056.6 | 1546.0 | 2602.6 | 1061.2 | 1740.9 | 2802.1 | 2.7470 | 3.3600 | 6.1070 |
| 250 | 3973.6 | 0.001251 | 0.04886 | 0.05011 | 1080.3 | 1521.3 | 2601.6 | 1085.3 | 1715.4 | 2800.7 | 2.7926 | 3.2791 | 6.0717 |
| 255 | 4320.2 | 0.001263 | 0.04470 | 0.04596 | 1104.3 | 1495.9 | 2600.2 | 1109.7 | 1689.1 | 2798.8 | 2.8382 | 3.1981 | 6.0363 |
| 260 | 4689.4 | 0.001276 | 0.04091 | 0.04219 | 1128.4 | 1470.0 | 2598.4 | 1134.4 | 1661.8 | 2796.2 | 2.8838 | 3.1171 | 6.0009 |
| 265 | 5082.3 | 0.001289 | 0.03747 | 0.03876 | 1152.8 | 1443.2 | 2596.0 | 1159.3 | 1633.7 | 2793.0 | 2.9294 | 3.0358 | 5.9652 |
| 270 | 5499.9 | 0.001303 | 0.03434 | 0.03564 | 1177.4 | 1415.8 | 2593.2 | 1184.6 | 1604.5 | 2789.1 | 2.9751 | 2.9542 | 5.9293 |
| 275 | 5943.1 | 0.001317 | 0.03146 | 0.03278 | 1202.3 | 1387.4 | 2589.7 | 1210.1 | 1574.4 | 2784.5 | 3.0209 | 2.8722 | 5.8931 |
| 280 | 6413.2 | 0.001332 | 0.02883 | 0.03016 | 1227.5 | 1358.2 | 2585.7 | 1236.1 | 1543.1 | 2779.2 | 3.0669 | 2.7896 | 5.8565 |
| 285 | 6911.1 | 0.001349 | 0.02642 | 0.02777 | 1253.1 | 1328.0 | 2581.1 | 1262.4 | 1510.6 | 2773.0 | 3.1131 | 2.7064 | 5.8195 |
| 290 | 7438.0 | 0.001366 | 0.02419 | 0.02556 | 1279.0 | 1296.7 | 2575.7 | 1289.1 | 1476.8 | 2765.9 | 3.1595 | 2.6223 | 5.7818 |
| 295 | 7995.2 | 0.001384 | 0.02216 | 0.02354 | 1305.3 | 1264.4 | 2569.7 | 1316.3 | 1441.5 | 2757.8 | 3.2062 | 2.5372 | 5.7454 |
| 300 | 8583.8 | 0.001404 | 0.02027 | 0.02167 | 1332.0 | 1230.8 | 2562.8 | 1344.1 | 1404.6 | 2748.7 | 3.2534 | 2.4569 | 5.7042 |
| 305 | 9205.1 | 0.001425 | 0.01852 | 0.01994 | 1359.2 | 1195.8 | 2555.0 | 1372.3 | 1366.2 | 2738.5 | 3.3010 | 2.3630 | 5.6640 |
| 310 | 9860.5 | 0.001447 | 0.01689 | 0.01834 | 1387.0 | 1159.2 | 2546.2 | 1401.2 | 1325.8 | 2727.0 | 3.3491 | 2.2735 | 5.6226 |
| 315 | 10,550 | 0.001472 | 0.01539 | 0.01686 | 1415.3 | 1121.0 | 2536.3 | 1430.8 | 1283.4 | 2714.2 | 3.3979 | 2.1820 | 5.5799 |
| 320 | 11,280 | 0.001498 | 0.01398 | 0.01548 | 1444.4 | 1080.8 | 2525.2 | 1461.3 | 1238.4 | 2699.7 | 3.4476 | 2.0880 | 5.5356 |
| 325 | 12,050 | 0.001528 | 0.01266 | 0.01419 | 1474.2 | 1038.4 | 2512.6 | 1492.6 | 1190.9 | 2683.5 | 3.4983 | 1.9910 | 5.4893 |
| 330 | 12,850 | 0.001560 | 0.01142 | 0.01298 | 1504.9 | 993.50 | 2498.4 | 1525.0 | 1140.3 | 2665.3 | 3.5501 | 1.8906 | 5.4407 |
| 335 | 13,700 | 0.001596 | 0.01025 | 0.01185 | 1536.8 | 945.50 | 2482.3 | 1558.6 | 1086.1 | 2644.7 | 3.6035 | 1.7854 | 5.3894 |
| 340 | 14,590 | 0.001637 | 0.009153 | 0.01079 | 1569.9 | 894.00 | 2463.9 | 1593.8 | 1027.5 | 2621.3 | 3.6587 | 1.6758 | 5.3345 |
| 345 | 15,530 | 0.001684 | 0.008094 | 0.009778 | 1604.7 | 838.00 | 2442.7 | 1630.9 | 963.60 | 2594.5 | 3.7164 | 1.5589 | 5.2753 |
| 350 | 16,520 | 0.001740 | 0.007072 | 0.008812 | 1641.7 | 776.20 | 2417.9 | 1670.4 | 893.10 | 2563.5 | 3.7774 | 1.4331 | 5.2105 |
| 355 | 17,560 | 0.001808 | 0.006071 | 0.007879 | 1681.5 | 706.90 | 2388.4 | 1713.3 | 813.40 | 2526.7 | 3.8429 | 1.2950 | 5.1379 |
| 360 | 18,660 | 0.001894 | 0.005068 | 0.006962 | 1725.6 | 626.60 | 2352.2 | 1761.0 | 721.00 | 2482.0 | 3.9153 | 1.1389 | 5.0542 |
| 365 | 19,810 | 0.002012 | 0.004017 | 0.006029 | 1776.8 | 528.40 | 2305.2 | 1816.7 | 607.90 | 2424.6 | 3.9994 | 0.9526 | 4.9520 |
| 370 | 21,030 | 0.002207 | 0.002786 | 0.004993 | 1843.3 | 391.90 | 2235.2 | 1889.7 | 450.50 | 2340.2 | 4.1094 | 0.7004 | 4.8098 |
| 373 | 22,055 | 0.00311 | - | 0.00311 | 2017 | - | 2017 | 2086 | - | 2086 | 4.409 | - | 4.409 |

# Table A2.3: Properties of WATER in Compressed Liquid State

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 5,000 | 10 | 0.000998 | 41.860 | 46.850 | 0.1505 |
| | 30 | 0.001002 | 125.21 | 130.22 | 0.4350 |
| | 50 | 0.001010 | 208.58 | 213.63 | 0.7014 |
| | 70 | 0.001020 | 291.97 | 297.07 | 0.9520 |
| | 90 | 0.001034 | 375.59 | 380.75 | 1.1890 |
| | 110 | 0.001049 | 459.63 | 464.88 | 1.4145 |
| | 130 | 0.001067 | 544.28 | 549.61 | 1.6301 |
| | 150 | 0.001087 | 629.68 | 635.12 | 1.8371 |
| | 170 | 0.001111 | 716.04 | 721.59 | 2.0367 |
| | 190 | 0.001138 | 803.64 | 809.33 | 2.2304 |
| | 210 | 0.001169 | 892.89 | 898.74 | 2.4193 |
| | 230 | 0.001206 | 984.40 | 990.43 | 2.6053 |
| | 250 | 0.001250 | 1079.0 | 1085.3 | 2.7901 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 10,000 | 10 | 0.000996 | 41.729 | 51.685 | 0.1500 |
| | 30 | 0.001000 | 124.75 | 134.75 | 0.4334 |
| | 50 | 0.001008 | 207.85 | 217.93 | 0.6991 |
| | 70 | 0.001018 | 290.98 | 301.16 | 0.9491 |
| | 90 | 0.001031 | 374.32 | 384.63 | 1.1855 |
| | 110 | 0.001046 | 458.07 | 468.53 | 1.4104 |
| | 130 | 0.001064 | 542.38 | 553.02 | 1.6253 |
| | 150 | 0.001084 | 627.41 | 638.25 | 1.8316 |
| | 170 | 0.001107 | 713.31 | 724.39 | 2.0305 |
| | 190 | 0.001133 | 800.37 | 811.70 | 2.2232 |
| | 210 | 0.001164 | 888.94 | 900.57 | 2.4111 |
| | 230 | 0.001199 | 979.55 | 991.54 | 2.5955 |
| | 250 | 0.001241 | 1073.0 | 1085.4 | 2.7784 |
| | 270 | 0.001292 | 1170.3 | 1183.2 | 2.9619 |
| | 290 | 0.001357 | 1273.5 | 1287.1 | 3.1497 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 15,000 | 10 | 0.000993 | 41.593 | 56.493 | 0.1494 |
| | 30 | 0.000998 | 124.30 | 139.27 | 0.4319 |
| | 50 | 0.001006 | 207.13 | 222.22 | 0.6968 |
| | 70 | 0.001016 | 290.01 | 305.25 | 0.9461 |
| | 90 | 0.001029 | 373.08 | 388.51 | 1.1820 |
| | 110 | 0.001044 | 456.54 | 472.20 | 1.4063 |
| | 130 | 0.001061 | 540.53 | 556.45 | 1.6206 |
| | 150 | 0.001081 | 625.19 | 641.41 | 1.8263 |
| | 170 | 0.001104 | 710.67 | 727.22 | 2.0244 |
| | 190 | 0.001129 | 797.20 | 814.14 | 2.2163 |
| | 210 | 0.001159 | 885.13 | 902.51 | 2.4030 |
| | 230 | 0.001193 | 974.91 | 992.80 | 2.5862 |
| | 250 | 0.001233 | 1067.2 | 1085.7 | 2.7672 |
| | 270 | 0.001281 | 1163.0 | 1182.2 | 2.9481 |
| | 290 | 0.001341 | 1263.7 | 1283.8 | 3.1319 |
| | 310 | 0.001421 | 1372.1 | 1393.5 | 3.3231 |
| | 330 | 0.001539 | 1494.7 | 1517.8 | 3.5327 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 20,000 | 10 | 0.000991 | 41.453 | 61.274 | 0.1488 |
| | 30 | 0.000996 | 123.86 | 143.77 | 0.4303 |
| | 50 | 0.001003 | 206.43 | 226.50 | 0.6946 |
| | 70 | 0.001014 | 289.05 | 309.33 | 0.9432 |
| | 90 | 0.001026 | 371.86 | 392.39 | 1.1785 |
| | 110 | 0.001041 | 455.04 | 475.87 | 1.4023 |
| | 130 | 0.001058 | 538.73 | 559.90 | 1.6160 |
| | 150 | 0.001078 | 623.03 | 644.59 | 1.8211 |
| | 170 | 0.001100 | 708.10 | 730.10 | 2.0185 |
| | 190 | 0.001125 | 794.14 | 816.64 | 2.2095 |
| | 210 | 0.001154 | 881.46 | 904.53 | 2.3953 |
| | 230 | 0.001187 | 970.48 | 994.21 | 2.5771 |
| | 250 | 0.001225 | 1061.8 | 1086.3 | 2.7565 |
| | 270 | 0.001271 | 1156.1 | 1181.5 | 2.9352 |
| | 290 | 0.001327 | 1254.7 | 1281.3 | 3.1155 |
| | 310 | 0.001399 | 1359.7 | 1387.7 | 3.3011 |
| | 330 | 0.001499 | 1475.0 | 1505.0 | 3.4988 |
| | 350 | 0.001665 | 1612.1 | 1645.4 | 3.7277 |

## Table A2.3: Properties of WATER in Compressed Liquid State (Continued)

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 30,000 | 10 | 0.000987 | 41.158 | 70.757 | 0.1473 |
| | 30 | 0.000992 | 122.99 | 152.73 | 0.4271 |
| | 50 | 0.000999 | 205.07 | 235.05 | 0.6900 |
| | 70 | 0.001010 | 287.20 | 317.49 | 0.9375 |
| | 90 | 0.001022 | 369.51 | 400.16 | 1.1717 |
| | 110 | 0.001036 | 452.15 | 483.24 | 1.3944 |
| | 130 | 0.001053 | 535.24 | 566.83 | 1.6070 |
| | 150 | 0.001072 | 618.87 | 651.03 | 1.8109 |
| | 170 | 0.001093 | 703.17 | 735.96 | 2.0070 |
| | 190 | 0.001117 | 788.29 | 821.81 | 2.1965 |
| | 210 | 0.001144 | 874.50 | 908.83 | 2.3804 |
| | 230 | 0.001175 | 962.13 | 997.39 | 2.5600 |
| | 250 | 0.001211 | 1051.6 | 1088.0 | 2.7365 |
| | 270 | 0.001253 | 1143.6 | 1181.2 | 2.9113 |
| | 290 | 0.001303 | 1238.8 | 1277.9 | 3.0862 |
| | 310 | 0.001364 | 1338.6 | 1379.5 | 3.2635 |
| | 330 | 0.001443 | 1444.9 | 1488.1 | 3.4466 |
| | 350 | 0.001552 | 1561.5 | 1608.1 | 3.6421 |
| | 370 | 0.001726 | 1697.8 | 1749.6 | 3.8656 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 50,000 | 10 | 0.000978 | 40.519 | 89.428 | 0.1439 |
| | 30 | 0.000984 | 121.31 | 170.48 | 0.4205 |
| | 50 | 0.000991 | 202.46 | 252.03 | 0.6810 |
| | 70 | 0.001001 | 283.69 | 333.76 | 0.9264 |
| | 90 | 0.001013 | 365.06 | 415.73 | 1.1585 |
| | 110 | 0.001027 | 446.70 | 498.06 | 1.3792 |
| | 130 | 0.001043 | 528.70 | 580.85 | 1.5898 |
| | 150 | 0.001061 | 611.12 | 664.16 | 1.7915 |
| | 170 | 0.001081 | 694.04 | 748.07 | 1.9853 |
| | 190 | 0.001103 | 777.56 | 832.70 | 2.1720 |
| | 210 | 0.001128 | 861.87 | 918.25 | 2.3529 |
| | 230 | 0.001155 | 947.19 | 1005.0 | 2.5287 |
| | 250 | 0.001187 | 1033.8 | 1093.2 | 2.7006 |
| | 270 | 0.001223 | 1122.1 | 1183.3 | 2.8696 |
| | 290 | 0.001264 | 1212.5 | 1275.8 | 3.0368 |
| | 310 | 0.001313 | 1305.6 | 1371.3 | 3.2035 |
| | 330 | 0.001371 | 1402.2 | 1470.7 | 3.3712 |
| | 350 | 0.001442 | 1503.2 | 1575.3 | 3.5417 |
| | 370 | 0.001533 | 1610.2 | 1686.9 | 3.7179 |

# Table A2.4: Properties of Superheated Steam

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 10 | (45.82) | (14.674) | (2437.0) | (2583.8) | (8.1482) |
| | 50 | 14.869 | 2443.1 | 2591.8 | 8.1731 |
| | 100 | 17.196 | 2515.0 | 2687.0 | 8.4471 |
| | 150 | 19.513 | 2587.4 | 2782.5 | 8.6873 |
| | 200 | 21.826 | 2660.8 | 2879.0 | 8.9030 |
| | 250 | 24.136 | 2735.5 | 2976.9 | 9.0995 |
| | 300 | 26.446 | 2811.7 | 3076.2 | 9.2808 |
| | 350 | 28.755 | 2889.5 | 3177.0 | 9.4494 |
| | 400 | 31.063 | 2968.8 | 3279.4 | 9.6075 |
| | 450 | 33.372 | 3049.7 | 3383.4 | 9.7565 |
| | 500 | 35.680 | 3132.4 | 3489.2 | 9.8979 |
| | 550 | 37.988 | 3216.7 | 3596.6 | 10.032 |
| | 600 | 40.296 | 3302.8 | 3705.7 | 10.161 |
| | 650 | 42.604 | 3390.6 | 3816.7 | 10.285 |
| | 700 | 44.912 | 3480.2 | 3929.4 | 10.404 |
| | 750 | 47.220 | 3571.6 | 4043.8 | 10.518 |
| | 800 | 49.527 | 3664.8 | 4160.1 | 10.629 |
| | 850 | 51.835 | 3759.7 | 4278.1 | 10.737 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 50 | (81.33) | (3.2408) | (2483.3) | (2645.3) | (7.5928) |
| | 100 | 3.4188 | 2511.2 | 2682.1 | 7.6941 |
| | 150 | 3.8895 | 2585.2 | 2779.7 | 7.9394 |
| | 200 | 4.3560 | 2659.4 | 2877.2 | 8.1572 |
| | 250 | 4.8205 | 2734.5 | 2975.6 | 8.3548 |
| | 300 | 5.2840 | 2811.0 | 3075.2 | 8.5367 |
| | 350 | 5.7469 | 2888.9 | 3176.2 | 8.7057 |
| | 400 | 6.2094 | 2968.3 | 3278.8 | 8.8640 |
| | 450 | 6.6717 | 3049.3 | 3382.9 | 9.0132 |
| | 500 | 7.1338 | 3132.0 | 3488.7 | 9.1547 |
| | 550 | 7.5958 | 3216.4 | 3596.2 | 9.2894 |
| | 600 | 8.0577 | 3302.5 | 3705.4 | 9.4182 |
| | 650 | 8.5195 | 3390.4 | 3816.4 | 9.5417 |
| | 700 | 8.9813 | 3480.1 | 3929.1 | 9.6606 |
| | 750 | 9.4430 | 3571.5 | 4043.6 | 9.7754 |
| | 800 | 9.9047 | 3664.7 | 4159.9 | 9.8863 |
| | 850 | 10.366 | 3759.6 | 4277.9 | 9.9938 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 100 | (99.63) | (1.6943) | (2505.7) | (2675.1) | (7.3589) |
| | 100 | 1.6961 | 2506.3 | 2675.9 | 7.3609 |
| | 150 | 1.9364 | 2582.4 | 2776.1 | 7.6129 |
| | 200 | 2.1723 | 2657.6 | 2874.8 | 7.8335 |
| | 250 | 2.4061 | 2733.3 | 2973.9 | 8.0325 |
| | 300 | 2.6388 | 2810.1 | 3073.9 | 8.2152 |
| | 350 | 2.8709 | 2888.2 | 3175.3 | 8.3846 |
| | 400 | 3.1027 | 2967.7 | 3278.0 | 8.5432 |
| | 450 | 3.3342 | 3048.9 | 3382.3 | 8.6927 |
| | 500 | 3.5655 | 3131.6 | 3488.2 | 8.8342 |
| | 550 | 3.7968 | 3216.1 | 3595.8 | 8.9690 |
| | 600 | 4.0279 | 3302.3 | 3705.0 | 9.0979 |
| | 650 | 4.2590 | 3390.2 | 3816.1 | 9.2216 |
| | 700 | 4.4900 | 3479.8 | 3928.8 | 9.3405 |
| | 750 | 4.7210 | 3571.3 | 4043.4 | 9.4553 |
| | 800 | 4.9519 | 3664.5 | 4159.7 | 9.5662 |
| | 850 | 5.1828 | 3759.4 | 4277.7 | 9.6738 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 101.33 | (100.00) | (1.6737) | (2506.1) | (2675.7) | (7.3545) |
| | 150 | 1.9108 | 2582.3 | 2776.0 | 7.6066 |
| | 200 | 2.1436 | 2657.5 | 2874.8 | 7.8273 |
| | 250 | 2.3744 | 2733.3 | 2973.8 | 8.0264 |
| | 300 | 2.6041 | 2810.0 | 3073.9 | 8.2090 |
| | 350 | 2.8332 | 2888.1 | 3175.2 | 8.3785 |
| | 400 | 3.0619 | 2967.7 | 3278.0 | 8.5371 |
| | 450 | 3.2904 | 3048.9 | 3382.3 | 8.6865 |
| | 500 | 3.5187 | 3131.6 | 3488.2 | 8.8281 |
| | 550 | 3.7469 | 3216.1 | 3595.8 | 8.9629 |
| | 600 | 3.9750 | 3302.2 | 3705.0 | 9.0918 |
| | 650 | 4.2030 | 3390.2 | 3816.1 | 9.2154 |
| | 700 | 4.4310 | 3479.8 | 3928.8 | 9.3344 |
| | 750 | 4.6590 | 3571.3 | 4043.4 | 9.4492 |
| | 800 | 4.8869 | 3664.5 | 4159.7 | 9.5601 |
| | 850 | 5.1148 | 3759.4 | 4277.7 | 9.6677 |

# Table A2.4: Properties of Superheated Steam (Continued)

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 200 | (120.24) | (0.8859) | (2529.4) | (2706.5) | (7.1272) |
| | 150 | 0.9597 | 2576.7 | 2768.6 | 7.2793 |
| | 200 | 1.0803 | 2653.9 | 2870.0 | 7.5059 |
| | 250 | 1.1988 | 2730.8 | 2970.5 | 7.7078 |
| | 300 | 1.3162 | 2808.2 | 3071.4 | 7.8920 |
| | 350 | 1.4329 | 2886.7 | 3173.3 | 8.0624 |
| | 400 | 1.5493 | 2966.6 | 3276.4 | 8.2216 |
| | 450 | 1.6655 | 3047.9 | 3381.0 | 8.3714 |
| | 500 | 1.7814 | 3130.8 | 3487.1 | 8.5133 |
| | 550 | 1.8973 | 3215.4 | 3594.9 | 8.6483 |
| | 600 | 2.0130 | 3301.7 | 3704.3 | 8.7773 |
| | 650 | 2.1287 | 3389.7 | 3815.4 | 8.9011 |
| | 700 | 2.2443 | 3479.4 | 3928.3 | 9.0201 |
| | 750 | 2.3599 | 3570.9 | 4042.9 | 9.1350 |
| | 800 | 2.4755 | 3664.1 | 4159.2 | 9.2460 |
| | 850 | 2.5910 | 3759.1 | 4277.3 | 9.3536 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 300 | (133.56) | (0.6059) | (2543.5) | (2725.3) | (6.9921) |
| | 150 | 0.6339 | 2570.7 | 2760.9 | 7.0779 |
| | 200 | 0.7163 | 2650.2 | 2865.1 | 7.3108 |
| | 250 | 0.7963 | 2728.2 | 2967.1 | 7.5157 |
| | 300 | 0.8753 | 2806.3 | 3068.9 | 7.7015 |
| | 350 | 0.9536 | 2885.3 | 3171.3 | 7.8729 |
| | 400 | 1.0315 | 2965.4 | 3274.9 | 8.0327 |
| | 450 | 1.1092 | 3047.0 | 3379.7 | 8.1830 |
| | 500 | 1.1867 | 3130.1 | 3486.1 | 8.3252 |
| | 550 | 1.2641 | 3214.7 | 3594.0 | 8.4604 |
| | 600 | 1.3414 | 3301.1 | 3703.5 | 8.5895 |
| | 650 | 1.4186 | 3389.1 | 3814.7 | 8.7134 |
| | 700 | 1.4958 | 3478.9 | 3927.7 | 8.8325 |
| | 750 | 1.5729 | 3570.5 | 4042.3 | 8.9475 |
| | 800 | 1.6500 | 3663.8 | 4158.8 | 9.0585 |
| | 850 | 1.7271 | 3758.8 | 4276.9 | 9.1661 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 400 | (143.64) | (0.4625) | (2553.5) | (2738.5) | (6.8961) |
| | 150 | 0.4708 | 2564.4 | 2752.8 | 6.9300 |
| | 200 | 0.5342 | 2646.4 | 2860.1 | 7.1699 |
| | 250 | 0.5951 | 2725.6 | 2963.6 | 7.3779 |
| | 300 | 0.6548 | 2804.4 | 3066.3 | 7.5654 |
| | 350 | 0.7139 | 2883.8 | 3169.4 | 7.7378 |
| | 400 | 0.7726 | 2964.3 | 3273.3 | 7.8982 |
| | 450 | 0.8311 | 3046.0 | 3378.5 | 8.0489 |
| | 500 | 0.8894 | 3129.3 | 3485.0 | 8.1914 |
| | 550 | 0.9475 | 3214.1 | 3593.1 | 8.3268 |
| | 600 | 1.0056 | 3300.5 | 3702.7 | 8.4561 |
| | 650 | 1.0636 | 3388.6 | 3814.1 | 8.5801 |
| | 700 | 1.1215 | 3478.5 | 3927.1 | 8.6993 |
| | 750 | 1.1794 | 3570.1 | 4041.8 | 8.8143 |
| | 800 | 1.2373 | 3663.4 | 4158.3 | 8.9254 |
| | 850 | 1.2951 | 3758.4 | 4276.5 | 9.0331 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 600 | (158.86) | (0.3156) | (2567.3) | (2756.7) | (6.7601) |
| | 200 | 0.3520 | 2638.5 | 2849.7 | 6.9658 |
| | 250 | 0.3938 | 2720.3 | 2956.6 | 7.1806 |
| | 300 | 0.4344 | 2800.5 | 3061.2 | 7.3716 |
| | 350 | 0.4742 | 2880.9 | 3165.4 | 7.5459 |
| | 400 | 0.5137 | 2961.9 | 3270.2 | 7.7076 |
| | 450 | 0.5529 | 3044.1 | 3375.9 | 7.8591 |
| | 500 | 0.5920 | 3127.7 | 3482.9 | 8.0022 |
| | 550 | 0.6309 | 3212.7 | 3591.2 | 8.1380 |
| | 600 | 0.6697 | 3299.3 | 3701.2 | 8.2676 |
| | 650 | 0.7085 | 3387.6 | 3812.7 | 8.3918 |
| | 700 | 0.7472 | 3477.6 | 3925.9 | 8.5112 |
| | 750 | 0.7859 | 3569.2 | 4040.8 | 8.6264 |
| | 800 | 0.8246 | 3662.7 | 4157.4 | 8.7376 |
| | 850 | 0.8632 | 3757.8 | 4275.7 | 8.8453 |

# Table A2.4: Properties of Superheated Steam (Continued)

| P kPa | T $^0$C | v m$^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 800 | (170.44) | (0.2404) | (2576.6) | (2768.9) | (6.6625) |
| | 200 | 0.2607 | 2630.2 | 2838.8 | 6.8151 |
| | 250 | 0.2931 | 2714.8 | 2949.3 | 7.0373 |
| | 300 | 0.3241 | 2796.6 | 3055.9 | 7.2319 |
| | 350 | 0.3544 | 2877.9 | 3161.4 | 7.4084 |
| | 400 | 0.3843 | 2959.6 | 3267.0 | 7.5713 |
| | 450 | 0.4139 | 3042.2 | 3373.3 | 7.7237 |
| | 500 | 0.4433 | 3126.1 | 3480.7 | 7.8673 |
| | 550 | 0.4726 | 3211.3 | 3589.4 | 8.0036 |
| | 600 | 0.5018 | 3298.1 | 3699.6 | 8.1335 |
| | 650 | 0.5310 | 3386.6 | 3811.4 | 8.2579 |
| | 700 | 0.5601 | 3476.7 | 3924.7 | 8.3775 |
| | 750 | 0.5892 | 3568.4 | 4039.8 | 8.4928 |
| | 800 | 0.6182 | 3661.9 | 4156.5 | 8.6041 |
| | 850 | 0.6472 | 3757.1 | 4274.9 | 8.7120 |

| P kPa | T $^0$C | v m$^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 1000 | (179.92) | (0.1944) | (2583.3) | (2781.2) | (6.5529) |
| | 200 | 0.2059 | 2621.5 | 2827.4 | 6.6932 |
| | 250 | 0.2326 | 2709.2 | 2941.9 | 6.9235 |
| | 300 | 0.2579 | 2792.7 | 3050.6 | 7.1219 |
| | 350 | 0.2825 | 2874.9 | 3157.3 | 7.3005 |
| | 400 | 0.3066 | 2957.2 | 3263.8 | 7.4648 |
| | 450 | 0.3304 | 3040.3 | 3370.7 | 7.6180 |
| | 500 | 0.3541 | 3124.5 | 3478.6 | 7.7622 |
| | 550 | 0.3776 | 3210.0 | 3587.6 | 7.8989 |
| | 600 | 0.4011 | 3297.0 | 3698.1 | 8.0292 |
| | 650 | 0.4245 | 3385.5 | 3810.0 | 8.1538 |
| | 700 | 0.4478 | 3475.7 | 3923.6 | 8.2736 |
| | 750 | 0.4711 | 3567.6 | 4038.7 | 8.3890 |
| | 800 | 0.4944 | 3661.2 | 4155.5 | 8.5005 |
| | 850 | 0.5176 | 3756.4 | 4274.0 | 8.6084 |

| P kPa | T $^0$C | v m$^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 1500 | (198.33) | (0.1317) | (2593.9) | (2791.5) | (6.4438) |
| | 200 | 0.1324 | 2597.5 | 2796.1 | 6.4536 |
| | 250 | 0.1519 | 2694.6 | 2922.4 | 6.7077 |
| | 300 | 0.1696 | 2782.5 | 3036.9 | 6.9168 |
| | 350 | 0.1866 | 2867.2 | 3147.1 | 7.1011 |
| | 400 | 0.2030 | 2951.2 | 3255.7 | 7.2687 |
| | 450 | 0.2192 | 3035.4 | 3364.2 | 7.4242 |
| | 500 | 0.2351 | 3120.4 | 3473.1 | 7.5699 |
| | 550 | 0.2510 | 3206.5 | 3583.0 | 7.7076 |
| | 600 | 0.2668 | 3294.0 | 3694.2 | 7.8386 |
| | 650 | 0.2825 | 3382.9 | 3806.6 | 7.9639 |
| | 700 | 0.2981 | 3473.4 | 3920.6 | 8.0841 |
| | 750 | 0.3137 | 3565.6 | 4036.1 | 8.1999 |
| | 800 | 0.3293 | 3659.3 | 4153.2 | 8.3116 |
| | 850 | 0.3448 | 3754.8 | 4272.0 | 8.4198 |

| P kPa | T $^0$C | v m$^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 2000 | (212.42) | (0.09959) | (2599.5) | (2798.7) | (6.3396) |
| | 250 | 0.1114 | 2678.8 | 2901.6 | 6.5438 |
| | 300 | 0.1254 | 2771.8 | 3022.7 | 6.7651 |
| | 350 | 0.1386 | 2859.4 | 3136.6 | 6.9556 |
| | 400 | 0.1512 | 2945.1 | 3247.5 | 7.1269 |
| | 450 | 0.1635 | 3030.5 | 3357.5 | 7.2845 |
| | 500 | 0.1757 | 3116.3 | 3467.7 | 7.4318 |
| | 550 | 0.1877 | 3203.1 | 3578.4 | 7.5706 |
| | 600 | 0.1996 | 3291.0 | 3690.2 | 7.7024 |
| | 650 | 0.2114 | 3380.3 | 3803.2 | 7.8283 |
| | 700 | 0.2232 | 3471.1 | 3917.6 | 7.9490 |
| | 750 | 0.2350 | 3563.5 | 4033.5 | 8.0651 |
| | 800 | 0.2467 | 3657.5 | 4150.9 | 8.1771 |
| | 850 | 0.2584 | 3753.1 | 4269.9 | 8.2855 |

## Table A2.4: Properties of Superheated Steam (Continued)

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 2500 | (223.99) | (0.07995) | (2602.3) | (2802.2) | (6.2560) |
| | 250 | 0.08698 | 2661.7 | 2879.1 | 6.4069 |
| | 300 | 0.09888 | 2760.8 | 3008.0 | 6.6424 |
| | 350 | 0.1097 | 2851.4 | 3125.8 | 6.8395 |
| | 400 | 0.1201 | 2938.9 | 3239.2 | 7.0146 |
| | 450 | 0.1301 | 3025.5 | 3350.9 | 7.1746 |
| | 500 | 0.1400 | 3112.2 | 3462.2 | 7.3235 |
| | 550 | 0.1497 | 3199.6 | 3573.8 | 7.4634 |
| | 600 | 0.1593 | 3288.0 | 3686.3 | 7.5960 |
| | 650 | 0.1688 | 3377.7 | 3799.8 | 7.7225 |
| | 700 | 0.1783 | 3468.8 | 3914.7 | 7.8436 |
| | 750 | 0.1878 | 3561.4 | 4030.9 | 7.9601 |
| | 800 | 0.1972 | 3655.6 | 4148.6 | 8.0724 |
| | 850 | 0.2066 | 3751.4 | 4267.9 | 8.1810 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 3000 | (233.89) | (0.06666) | (2603.3) | (2803.3) | (6.1855) |
| | 250 | 0.07056 | 2643.1 | 2854.8 | 6.2857 |
| | 300 | 0.08113 | 2749.2 | 2992.6 | 6.5375 |
| | 350 | 0.09052 | 2843.2 | 3114.8 | 6.7420 |
| | 400 | 0.09935 | 2932.7 | 3230.7 | 6.9210 |
| | 450 | 0.1079 | 3020.5 | 3344.1 | 7.0835 |
| | 500 | 0.1162 | 3108.1 | 3456.6 | 7.2339 |
| | 550 | 0.1244 | 3196.1 | 3569.1 | 7.3750 |
| | 600 | 0.1324 | 3285.0 | 3682.3 | 7.5084 |
| | 650 | 0.1404 | 3375.1 | 3796.4 | 7.6355 |
| | 700 | 0.1484 | 3466.5 | 3911.7 | 7.7571 |
| | 750 | 0.1563 | 3559.4 | 4028.3 | 7.8739 |
| | 800 | 0.1642 | 3653.8 | 4146.3 | 7.9865 |
| | 850 | 0.1720 | 3749.7 | 4265.8 | 8.0954 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 4000 | (250.39) | (0.04977) | (2601.5) | (2800.6) | (6.0689) |
| | 300 | 0.05882 | 2724.4 | 2959.7 | 6.3598 |
| | 350 | 0.06644 | 2826.1 | 3091.8 | 6.5811 |
| | 400 | 0.07340 | 2919.8 | 3213.4 | 6.7688 |
| | 450 | 0.08002 | 3010.3 | 3330.4 | 6.9364 |
| | 500 | 0.08642 | 3099.7 | 3445.4 | 7.0902 |
| | 550 | 0.09268 | 3189.0 | 3559.7 | 7.2335 |
| | 600 | 0.09884 | 3278.9 | 3674.3 | 7.3687 |
| | 650 | 0.1049 | 3369.8 | 3789.5 | 7.4970 |
| | 700 | 0.1110 | 3461.8 | 3905.7 | 7.6195 |
| | 750 | 0.1170 | 3555.2 | 4023.0 | 7.7371 |
| | 800 | 0.1229 | 3650.0 | 4141.7 | 7.8503 |
| | 850 | 0.1288 | 3746.3 | 4261.7 | 7.9596 |

| P kPa | T $^0C$ | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 5000 | (263.98) | (0.03944) | (2596.5) | (2793.7) | (5.9725) |
| | 300 | 0.04530 | 2697.0 | 2923.5 | 6.2067 |
| | 350 | 0.05193 | 2808.0 | 3067.7 | 6.4482 |
| | 400 | 0.05781 | 2906.5 | 3195.5 | 6.6456 |
| | 450 | 0.06330 | 2999.8 | 3316.3 | 6.8187 |
| | 500 | 0.06856 | 3091.1 | 3433.9 | 6.9760 |
| | 550 | 0.07367 | 3181.8 | 3550.2 | 7.1218 |
| | 600 | 0.07869 | 3272.8 | 3666.2 | 7.2586 |
| | 650 | 0.08362 | 3364.5 | 3782.6 | 7.3882 |
| | 700 | 0.08850 | 3457.1 | 3899.7 | 7.5117 |
| | 750 | 0.09334 | 3551.0 | 4017.7 | 7.6300 |
| | 800 | 0.09815 | 3646.3 | 4137.0 | 7.7438 |
| | 850 | 0.1029 | 3742.9 | 4257.5 | 7.8536 |

# Table A2.4: Properties of Superheated Steam (Continued)

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 6000 | (275.62) | (0.03244) | (2589.3) | (2783.9) | (5.8886) |
| | 300 | 0.03615 | 2666.3 | 2883.2 | 6.0659 |
| | 350 | 0.04222 | 2788.9 | 3042.2 | 6.3322 |
| | 400 | 0.04739 | 2892.7 | 3177.0 | 6.5404 |
| | 450 | 0.05214 | 2989.1 | 3301.9 | 6.7195 |
| | 500 | 0.05665 | 3082.4 | 3422.3 | 6.8805 |
| | 550 | 0.06100 | 3174.6 | 3540.6 | 7.0287 |
| | 600 | 0.06525 | 3266.6 | 3658.1 | 7.1673 |
| | 650 | 0.06942 | 3359.1 | 3775.6 | 7.2982 |
| | 700 | 0.07353 | 3452.4 | 3893.6 | 7.4227 |
| | 750 | 0.07760 | 3546.8 | 4012.4 | 7.5418 |
| | 800 | 0.08164 | 3642.5 | 4132.3 | 7.6561 |
| | 850 | 0.08565 | 3739.5 | 4253.4 | 7.7664 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 7000 | (285.86) | (0.02737) | (2580.2) | (2771.8) | (5.8130) |
| | 300 | 0.02946 | 2631.4 | 2837.6 | 5.9293 |
| | 350 | 0.03523 | 2768.5 | 3015.1 | 6.2269 |
| | 400 | 0.03993 | 2878.4 | 3157.9 | 6.4474 |
| | 450 | 0.04416 | 2978.1 | 3287.3 | 6.6329 |
| | 500 | 0.04813 | 3073.6 | 3410.5 | 6.7978 |
| | 550 | 0.05194 | 3167.2 | 3530.8 | 6.9486 |
| | 600 | 0.05565 | 3260.3 | 3649.8 | 7.0889 |
| | 650 | 0.05927 | 3353.6 | 3768.5 | 7.2211 |
| | 700 | 0.06284 | 3447.6 | 3887.5 | 7.3466 |
| | 750 | 0.06636 | 3542.6 | 4007.1 | 7.4665 |
| | 800 | 0.06985 | 3638.7 | 4127.6 | 7.5815 |
| | 850 | 0.07331 | 3736.1 | 4249.2 | 7.6922 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 8000 | (295.04) | (0.02352) | (2569.6) | (2757.8) | (5.7431) |
| | 300 | 0.02426 | 2590.5 | 2784.6 | 5.7901 |
| | 350 | 0.02995 | 2746.7 | 2986.3 | 6.1286 |
| | 400 | 0.03431 | 2863.5 | 3138.0 | 6.3630 |
| | 450 | 0.03816 | 2966.9 | 3272.2 | 6.5554 |
| | 500 | 0.04174 | 3064.6 | 3398.5 | 6.7243 |
| | 550 | 0.04515 | 3159.8 | 3521.0 | 6.8778 |
| | 600 | 0.04845 | 3254.0 | 3641.5 | 7.0200 |
| | 650 | 0.05166 | 3348.1 | 3761.4 | 7.1535 |
| | 700 | 0.05482 | 3442.8 | 3881.4 | 7.2800 |
| | 750 | 0.05793 | 3538.3 | 4001.7 | 7.4007 |
| | 800 | 0.06101 | 3634.9 | 4122.9 | 7.5163 |
| | 850 | 0.06406 | 3732.6 | 4245.1 | 7.6275 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 10,000 | (311.03) | (0.01803) | (2544.2) | (2724.5) | (5.6139) |
| | 350 | 0.02242 | 2698.1 | 2922.2 | 5.9425 |
| | 400 | 0.02641 | 2832.0 | 3096.1 | 6.2114 |
| | 450 | 0.02975 | 2943.6 | 3241.1 | 6.4194 |
| | 500 | 0.03278 | 3046.2 | 3374.0 | 6.5971 |
| | 550 | 0.03563 | 3144.6 | 3500.9 | 6.7561 |
| | 600 | 0.03836 | 3241.1 | 3624.7 | 6.9022 |
| | 650 | 0.04101 | 3337.1 | 3747.1 | 7.0385 |
| | 700 | 0.04359 | 3433.1 | 3869.0 | 7.1671 |
| | 750 | 0.04613 | 3529.7 | 3991.0 | 7.2893 |
| | 800 | 0.04863 | 3627.2 | 4113.5 | 7.4062 |
| | 850 | 0.05110 | 3725.7 | 4236.7 | 7.5184 |

# Table A2.4: Properties of Superheated Steam (Continued)

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 15,000 | (342.19) | (0.01034) | (2455.0) | (2610.1) | (5.3092) |
| | 350 | 0.01147 | 2519.3 | 2691.3 | 5.4404 |
| | 400 | 0.01565 | 2739.9 | 2974.7 | 5.8799 |
| | 450 | 0.01845 | 2879.9 | 3156.6 | 6.1410 |
| | 500 | 0.02080 | 2997.3 | 3309.3 | 6.3452 |
| | 550 | 0.02292 | 3104.9 | 3448.8 | 6.5201 |
| | 600 | 0.02490 | 3207.9 | 3581.5 | 6.6767 |
| | 650 | 0.02679 | 3308.6 | 3710.5 | 6.8204 |
| | 700 | 0.02862 | 3408.3 | 3837.6 | 6.9544 |
| | 750 | 0.03039 | 3507.8 | 3963.7 | 7.0808 |
| | 800 | 0.03213 | 3607.6 | 4089.6 | 7.2009 |
| | 850 | 0.03384 | 3708.1 | 4215.6 | 7.3158 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 20,000 | (365.80) | (0.005874) | (2296.1) | (2413.6) | (4.9330) |
| | 400 | 0.009946 | 2617.9 | 2816.9 | 5.5521 |
| | 450 | 0.01270 | 2806.8 | 3060.8 | 5.9026 |
| | 500 | 0.01477 | 2944.1 | 3239.4 | 6.1417 |
| | 550 | 0.01655 | 3063.0 | 3393.9 | 6.3355 |
| | 600 | 0.01817 | 3173.3 | 3536.7 | 6.5039 |
| | 650 | 0.01969 | 3279.2 | 3672.9 | 6.6557 |
| | 700 | 0.02113 | 3382.8 | 3805.5 | 6.7955 |
| | 750 | 0.02253 | 3485.4 | 3936.0 | 6.9263 |
| | 800 | 0.02388 | 3587.8 | 4065.4 | 7.0498 |
| | 850 | 0.02521 | 3690.3 | 4194.4 | 7.1673 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 25,000 | 500 | 0.01112 | 2886.1 | 3164.2 | 5.9616 |
| | 550 | 0.01272 | 3018.6 | 3336.5 | 6.1778 |
| | 600 | 0.01413 | 3137.3 | 3490.4 | 6.3593 |
| | 650 | 0.01542 | 3249.0 | 3634.5 | 6.5198 |
| | 700 | 0.01664 | 3356.8 | 3773.0 | 6.6659 |
| | 750 | 0.01781 | 3462.7 | 3908.0 | 6.8012 |
| | 800 | 0.01894 | 3567.6 | 4041.1 | 6.9282 |
| | 850 | 0.02003 | 3672.3 | 4173.1 | 7.0485 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 30,000 | 500 | 0.008676 | 2823.2 | 3083.5 | 5.7936 |
| | 550 | 0.01016 | 2972.0 | 3276.8 | 6.0362 |
| | 600 | 0.01143 | 3100.1 | 3443.1 | 6.2324 |
| | 650 | 0.01258 | 3218.0 | 3595.5 | 6.4022 |
| | 700 | 0.01365 | 3330.4 | 3740.1 | 6.5547 |
| | 750 | 0.01467 | 3439.7 | 3879.8 | 6.6948 |
| | 800 | 0.01564 | 3547.3 | 4016.7 | 6.8254 |
| | 850 | 0.01659 | 3654.2 | 4151.8 | 6.9484 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 35,000 | 600 | 0.009511 | 3061.9 | 3394.7 | 6.1174 |
| | 650 | 0.01056 | 3186.5 | 3556.0 | 6.2971 |
| | 700 | 0.01152 | 3303.6 | 3706.9 | 6.4563 |
| | 750 | 0.01243 | 3416.5 | 3851.6 | 6.6012 |
| | 800 | 0.01330 | 3526.9 | 3992.2 | 6.7355 |
| | 850 | 0.01413 | 3636.0 | 4130.4 | 6.8614 |

| P kPa | T $^0$C | v $m^3$/kg | u kJ/kg | h kJ/kg | s kJ/kg.K |
|---|---|---|---|---|---|
| 40,000 | 650 | 0.009046 | 3154.5 | 3516.3 | 6.2012 |
| | 700 | 0.009930 | 3276.6 | 3673.8 | 6.3673 |
| | 750 | 0.01075 | 3393.1 | 3823.3 | 6.5171 |
| | 800 | 0.01154 | 3506.4 | 3967.8 | 6.6551 |
| | 850 | 0.01229 | 3617.7 | 4109.2 | 6.7838 |