

SECTION – AThere are **FOUR** questions in this section. Answer any **THREE**.

1. (a) A 15-mm diameter hole is drilled in a piece of 20-mm-thick steel plate; the hole is then countersunk as shown in Fig. for Q. No. 1(a). Determine the volume of steel material removed during the countersinking process. **(23)**
 (b) The 10-kg block *A* is at rest against the 50-kg block *B* as shown in Fig. for Q. No. 1(b). The coefficient of static friction μ_s is the same between blocks *A* and *B* and between Block *B* and the floor, while friction between block *A* and the wall can be neglected. Knowing that $P = 150$ N, determine the value of μ_s for which motion is impending. **(23 $\frac{2}{3}$)**

2. (a) The rectangular platform is hinged at *A* and *B* and is supported by a cable that passes over a frictionless hook at *E* as shown in Fig. for Q. No. 2(a). Knowing that the tension in the cable is 1349 N, determine the moment about each of the coordinate axes of the force exerted by the cable at *D*. **(23)**
 (b) The member *ACD* is supported with a cable *ABD* and hinged at point *C* as shown in Fig. for Q. No. 2(b). Neglecting friction, determine the tension in cable *ABD* and the reaction at *C* in terms of P when $\theta = 40^\circ$. **(23 $\frac{2}{3}$)**

3. (a) Determine the force in members *AB*, *BD*, and *DE* of the truss shown in Fig. for Q. No. 3(a). State whether each member is in tension or compression. **(23)**
 (b) For the frame and loading shown in Fig. for Q. No. 3(b), determine the components of all forces acting on member *DECF*. **(23 $\frac{2}{3}$)**

4. (a) Determine the centroid of the plane area as shown in Fig. for Q. No. 4(a). **(23)**
 (b) Determine by direct integration the moment of inertia of the shaded area with respect to the *x* axis (see Fig. for Q. No. 4(b)). **(23 $\frac{2}{3}$)**

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SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Water flows from a drain spout with an initial velocity of 0.75 m/s at an angle of 15° with the horizontal, as shown in Fig. for Q. No. 5(a). Determine the range of values of the distance d for which the water will enter the trough BC . (23)
- (b) The two blocks shown in Fig. for Q. No. 5(b) are originally at rest. Neglecting the masses of the pulleys and the effect of friction in the pulleys and assuming that the kinetic coefficients of friction between block A and the horizontal surface is $\mu_k = 0.20$, determine (i) the acceleration of each block, (ii) the tension in the cable. $(23 \frac{2}{3})$
6. (a) A 3-kg collar C slides on a frictionless vertical rod, as shown in Fig. for Q. No. 6(a). It is pushed up into the position shown, compressing the upper spring by 50 mm and released. Determine (i) the maximum deflection of the lower spring, (ii) the maximum velocity of the collar. (23)
- (b) A 3-kg sphere A strikes the frictionless inclined surface of a 6-kg wedge B at a 90° angle with a velocity of magnitude 4 m/s, as shown in Fig. for Q. No. 6(b). The wedge can roll freely on the ground and is initially at rest. Knowing that the coefficient of restitution between the wedge and the sphere is 0.60 and that the inclined surface of the wedge forms an angle $\theta = 40^\circ$ with the horizontal, determine (i) the velocities of the sphere and of the wedge immediately after impact, (ii) the energy lost due to the impact. $(23 \frac{2}{3})$
7. (a) At the instant shown in Fig. for Q. No. 7(a), bar AB has a constant angular velocity of 25 rad/s counterclockwise. Determine at that instant - (i) the angular velocity of the rectangular plate $FBDH$, (ii) the velocity of point F . (23)
- (b) At the instant shown in Fig. for Q. No. 7(b), bar AB has a constant angular velocity of 4 rad/s (clockwise). At this instant, bars BD and DE have angular velocities of 3.6 rad/s (clockwise) and 6 rad/s (anti-clockwise), respectively. Determine the angular acceleration (i) of bar BD , (ii) of bar DE . $(23 \frac{2}{3})$
8. (a) A 5-m uniform beam of mass 100 kg is lowered by means of two cables unwinding from overhead cranes, as shown in Fig. for Q. No. 8(a). As the beam approaches the ground, the crane operators apply brakes to slow the unwinding motion. Knowing that the deceleration of cable A is 6 m/s^2 and the deceleration of cable B is 1 m/s^2 , determine the tension in each cable. (23)
- (b) A 2.0 kg slender rod is welded to a 5 kg uniform disk as shown. The assembly swings freely about C in a vertical plane, as shown in Fig. for Q. No. 8(b). Knowing that in the position shown the assembly has an angular velocity of 15 rad/s clockwise, determine (i) the angular acceleration of the assembly, and (ii) the components of the reaction at C . $(23 \frac{2}{3})$

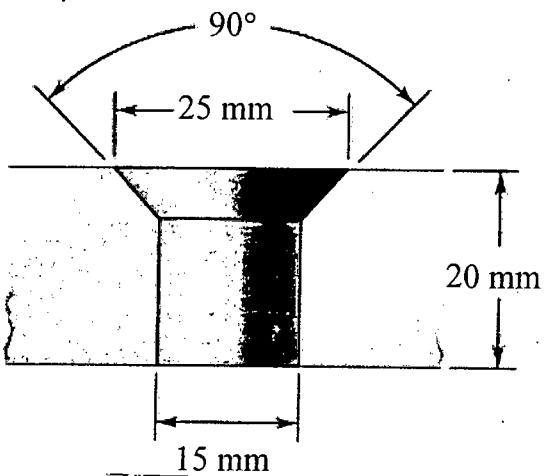


Fig. for Q. No. 1(a)

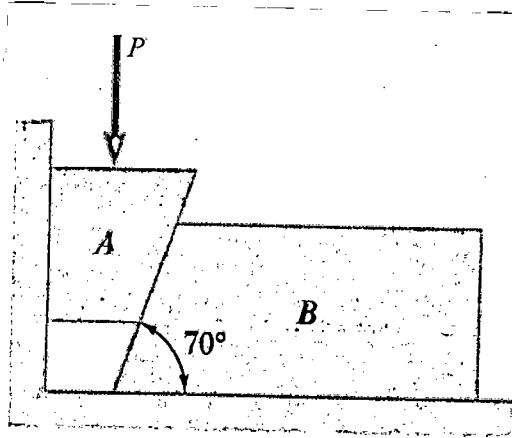


Fig. for Q. No. 1(b)

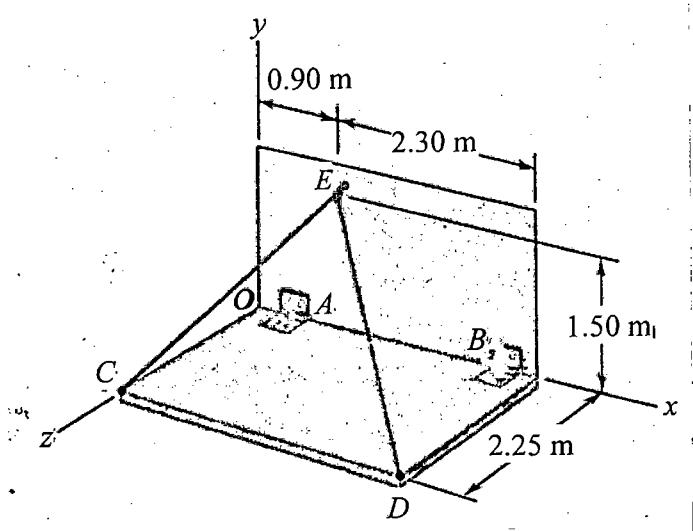


Fig. for Q. No. 2(a)

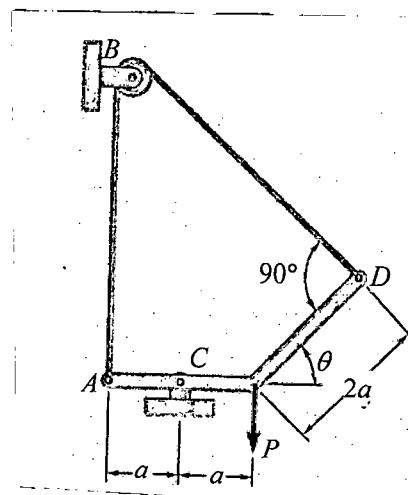


Fig. for Q. No. 2(b)

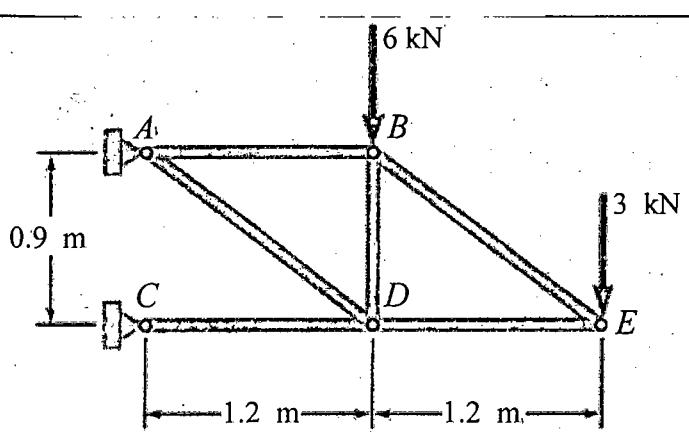


Fig. for Q. No. 3(a)

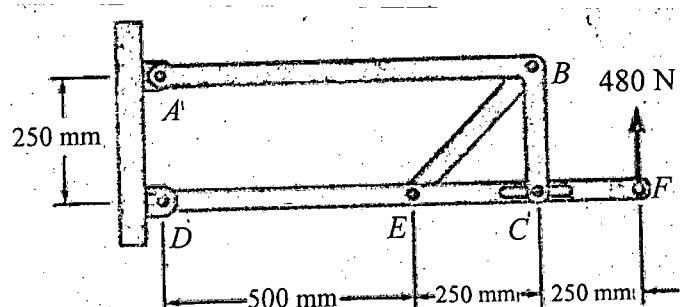


Fig. for Q. No. 3(b)

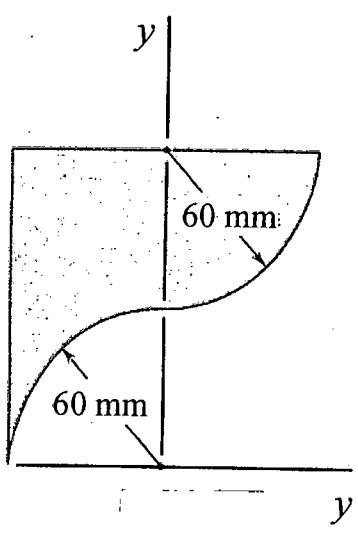


Fig. for Q. No. 4(a)

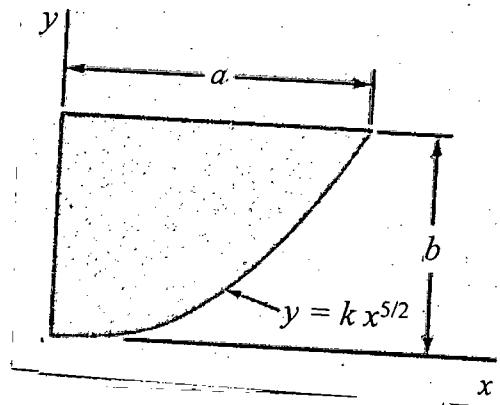


Fig. for Q. No. 4(b)

= 4 =

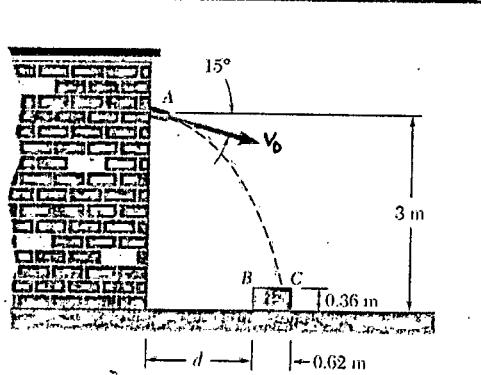


Fig. for Q. No. 5(a)

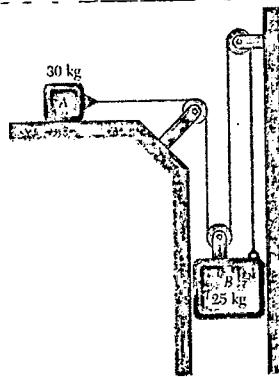


Fig. for Q. No. 5(b)

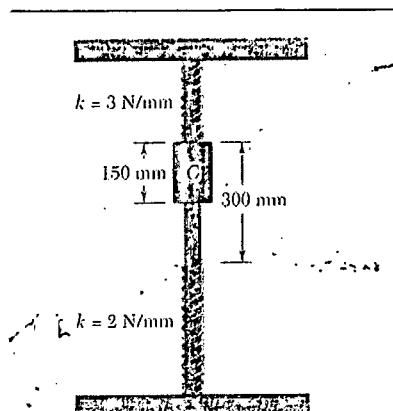


Fig. for Q. No. 6(a)

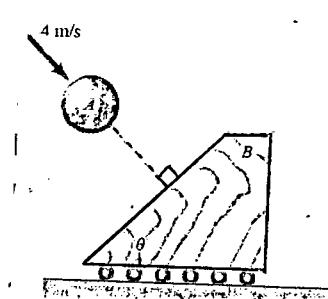


Fig. for Q. No. 6(b)

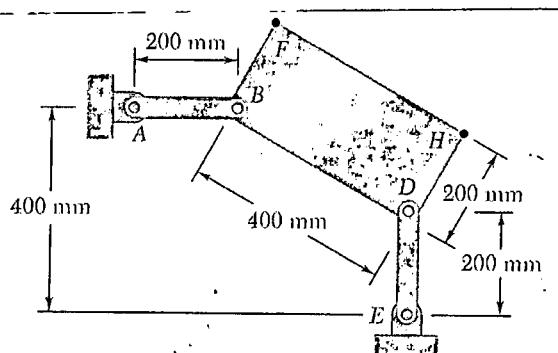


Fig for Q. No. 7(a)

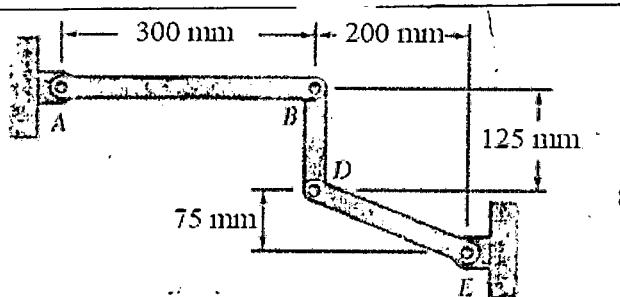


Fig. for Q. No. 7(b)

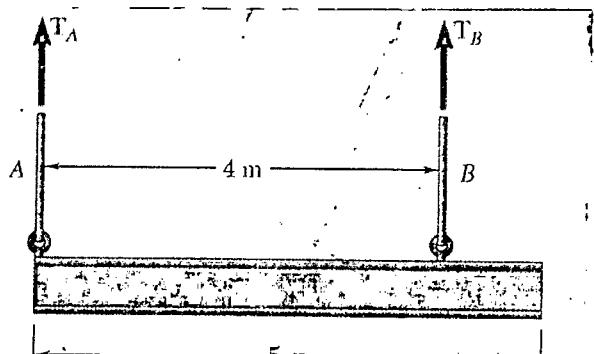


Fig. for Q. No. 8(a)

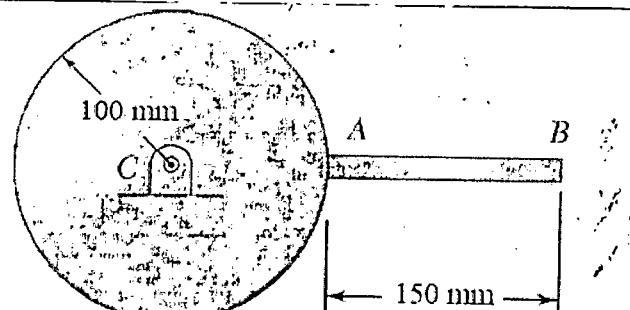


Fig. for Q. No. 8(b)

Sub : **MATH 261** (Vector Calculus, Matrices, Laplace Transform and Series Solution)

Full Marks: 280

Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

SECTION - AThere are **FOUR** questions in this section. Answer any **THREE**.

1. (a) For which values of '
- a
- ' will the system

(23 2/3)

$$4x + y + 2z = 6$$

$$3x - y + 5z = 2$$

$$4x + y + (a^2 - 14)z = a + 2$$

have (i) Unique solution? (ii) Infinitely many solutions? (iii) No solution?

(b) Reduce the following matrix A to echelon form then to its canonical form and write down the rank and nullity of A.

(23)

$$A = \begin{pmatrix} 2 & 7 & 3 & 5 \\ 1 & 2 & 3 & 4 \\ 3 & 8 & 1 & -2 \\ 4 & 13 & 1 & -1 \end{pmatrix}$$

2. (a) Test whether the vectors
- $\underline{u} = (3, 2, -1, 1)$
- ,
- $\underline{v} = (1, 1, -1, 2)$
- ,
- $\underline{w} = (1, 2, 0, -1)$
- and
- $\underline{x} = (4, 2, -3, 6)$
- are linearly independent. If not, then express
- \underline{x}
- as a linear combination of
- \underline{u}
- ,
- \underline{v}
- and
- \underline{w}
- .

(22)

- (b) Find the eigen values and corresponding eigen vectors of the matrix

(24 2/3)

$$A = \begin{pmatrix} 5 & 4 & -1 \\ 4 & 5 & -1 \\ -4 & -4 & 2 \end{pmatrix}$$

Is the matrix A diagonalizable? If so, then write down a nonsingular matrix P that diagonalizes A, and the diagonal matrix D.

3. (a) (i) Show that
- $\nabla\phi$
- is a vector perpendicular to the surface
- $\phi(x,y,z) = c$
- where
- c
- is a constant.

(6)

- (ii) What is directional derivative? Find the directional derivative of
- $\phi = x^2yz + 4xz^2$
- at the point
- $(1, -2, -1)$
- in the direction
- $2\mathbf{i} - \mathbf{j} - 2\mathbf{k}$
- . What is the magnitude of maximum rate of change of
- $\phi(x,y,z)$
- at
- $(1, -2, -1)$
- and in which direction?

(18)

- (b) Find the work done in moving a particle once around a circle C in the xy plane, if the circle has center at the origin and radius 3 and if the force field is given by

(22 2/3)

$$\mathbf{F} = (2x - y + z)\mathbf{i} + (x + y - z^2)\mathbf{j} + (3x - 2y + 4z)\mathbf{k}$$

4. (a) Write down the divergence theorem and verify it for
- $\mathbf{A} = 4x\mathbf{i} - 2y^2\mathbf{j} + z^2\mathbf{k}$
- taken over the region bounded by
- $x^2 + y^2 = 4$
- ,
- $z = 0$
- and
- $z = 3$
- .

(30)

- (b) Use Green's theorem to find the area bounded by one arch of the cycloid

(16 2/3)

$$\begin{aligned} x &= a(\theta - \sin \theta) \\ y &= a(1 - \cos \theta), \quad (a > 0) \end{aligned}$$

and the x-axis.

MATH 261

SECTION - B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Solve the following differential equation by the method of Fröbenius (36)

$$(x - x^2)y'' + (1 - 5x)y' - 4y = 0$$

- (b) Show that $\frac{d}{dx} [xJ_n(x)J_{n+1}(x)] = x[J_n^2(x) - J_{n+1}^2(x)]$. (10%)

6. (a) Prove that when n is a positive integer, $J_n(x)$ is the coefficient of z^n in the expansion of $e^{x(z-\frac{1}{z})/2}$ in ascending and descending power of z . Also prove that $J_n(x)$ is the coefficient of z^{-n} multiplied by $(-1)^n$ in the expansion of above expression. (16%)

- (b) Show that $\int_0^x z^{-n} J_{n+1}(z) dz = \frac{1}{2^n n!} - x^{-n} J_n(x)$. (15)

- (c) Show that $xP'_n(x) - P'_{n-1}(x) = nP_n(x)$. (15)

7. (a) Prove the Rodrigue's formula: (20%)

$$P_n(x) = \frac{1}{2^n n!} \frac{d^n}{dx^n} (x^2 - 1)^n.$$

- (b) Find $L\{J_0(t)\}$, where $J_0(t)$ is the Bessel's function of order zero. Hence find $L\{J_0(at)\}$ and $L\{J_1(at)\}$. (13)

- (c) Find $L\left\{ \frac{2}{\sqrt{\pi}} \int_0^{\sqrt{t}} e^{-u^2} du \right\}$. (13)

8. (a) Using Laplace transformation ,evaluate $\int_0^\infty \frac{\sin tx}{x(1+x^2)} dx$. (10%)

- (b) State and prove the Heaviside Expansion Formula for inverse Laplace transform.

- Using above formula find $L^{-1}\left\{ \frac{1+3s}{(s^2+1)(s-1)} \right\}$. (16)

- (c) Using Laplace transformation solve: (20)

$$2x(t) - y(t) - y'(t) = 4(1 - e^{-t})$$

$$2x(t) + y(t) = 2(1 + 3e^{-2t})$$

$$\text{and } x(0) = y(0) = 0.$$

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Define step-up, step-down and unit transformer. Why unit transformers are used in a power system? **(6 2/3)**
 (b) A single phase power system consists of a 480 V 60 Hz generator supplying a load $Z_{load} = 4 + j3 \Omega$ through a transmission line of impedance $Z_{line} = 0.18 + j0.24 \Omega$ **(30)**
 (i) If the power system is exactly as described above, what will be the voltage at the load? What will be the transmission line losses?
 (ii) Suppose a 1:10 step-up transformer is placed at the generator end of the transmission line and a 10:1 step-down transformer is placed at the load end of the line.
 What is the load voltage? What are the transmission line losses?
 (c) Draw the phasor diagram of a transformer operating at lagging power factor, unity power factor and leading power factor. Comment on the voltage regulation for each of the cases. **(10)**

2. (a) Write the advantages of using the per-unit system of measurements. **(6 2/3)**
 (b) The equivalent circuit impedances, referred to the primary side, of a 30 kVA, 8000/240 V, 60 Hz transformer are, **(16)**

$$\begin{array}{ll} R_{eq} = 38.4 \Omega & X_{eq} = 192 \Omega \\ R_c = 159 \text{ K}\Omega & X_m = 38.4 \text{ K}\Omega \end{array}$$

 (i) Determine the per-unit equivalent circuit of the transformer referred to the secondary side.
 (ii) Suppose that given transformer is included in a system that has more than one transformer. The total system has the base quantities as 15 kVA, 6000/230 V. Determine the per-unit values of the given impedances using the base values of the total system.
 (c) A 5000 kVA 230/13.8 kV single-phase power transformer has a per-unit resistance of 1 percent and a per-unit reactance of 5 percent (data taken from the transformer's nameplate). The open circuit test performed on the low-voltage side of the transformer yielded the following data: **(24)**

$$V_{OC} = 13.8 \text{ kV} \quad I_{OC} = 15.1 \text{ A} \quad P_{OC} = 44.9 \text{ kW}$$

- (i) Find the equivalent circuit referred to the low-voltage side of this transformer.
 (ii) If the voltage on the secondary side is 13.8 KV and the power supplied is 4000 KW at 0.8 pF lagging, find the voltage regulation of the transformer. Find its efficiency.

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3. (a) What is the speed regulation of a DC motor? How the speed of a shunt DC motor can be controlled by changing the field resistance and armature voltage? (2 $\frac{2}{3}$ + 16)
- (b) Derive the expression for the terminal characteristics of a series DC motor. (10)
- (c) Briefly discuss the problems on starting of a DC motor. Describe the starting circuit of a DC motor using countervoltage-sensing relays to cut out the starting resistor. (18)
4. (a) Draw the power flow diagram for a DC motor. (6 $\frac{2}{3}$)
- (b) A 300 hp, 440 V, 560 A, 863 rpm shunt dc motor has been tested, and the following data were taken: (24)

Blocked-rotor test:

$$\begin{array}{ll} V_A = 16.3 \text{ V exclusive of brushes} & V_F = 440 \text{ V} \\ I_A = 500 \text{ A} & I_F = 8.86 \text{ A} \end{array}$$

No-load Operation::

$$\begin{array}{ll} V_A = 16.3 \text{ V exclusive of brushes} & I_F = 8.76 \text{ A} \\ I_A = 23.1 \text{ A} & n = 863 \text{ rpm} \end{array}$$

What is this motor's efficiency at the rated conditions?

- (c) Describe the voltage build up in a shunt DC generator. Discuss the possible causes for the voltage to fail to build up during the starting of a shunt DC generator. (16)

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Derive an expression for the small signal resistance to a diode. Also state the condition for which the small signal approximation is valid. (10 $\frac{2}{3}$)
- (b) Explain with neat sketch of the circuit diagram and input/output waveshape, the principle of operation of a bridge rectifier. Also find the PIV of each diode. (10)
- (c) Find the values of I and V in the circuit shown in Fig. for q. 5(c). (13+13)
(Assume the diodes to be ideal)
6. (a) Explain the transfer characteristics of a basic common-emitter amplifier circuit with a neat sketch. (16)
- (b) "To operate the BJT as a linear amplifier, it must be biased at a point in the active region" — Explain why? (10 $\frac{2}{3}$)
- (c) For the circuit shown in Fig. for Q. 6(c). Find— (20)
- Small-signal equivalent circuit
 - Voltage gain A_v .

EEE 259

7. (a) "If a three phase set of currents, each of equal magnitude and differing in phase by 120° , flows in a three phase winding, then it will produce a rotating magnetic field of constant magnitude. (16)
 (b) Derive a model of the equivalent circuit of a synchronous generator. (20)
 (c) Why parallel operation of synchronous generators is required? Write down the conditions required for paralleling? (10 $\frac{2}{3}$)

8. (a) A 460 V, 25 HP, 60-Hz, four pole, Y connected induction motor has the following impedances in ohm per phase referred to the stator circuit: (23 $\frac{2}{3}$)

$$\begin{array}{ll} R_1 = 0.641 \Omega & R_2 = 0.332 \Omega \\ X_1 = 1.106 \Omega & X_2 = 0.464 \Omega \\ X_M = 26.3 \Omega & \end{array}$$

The total rotational losses are 1100 W and are assumed to be constant. Core loss is lumped with rotational loss. For a rotor slip of 2.2 percent at the rated voltage and rated frequency, find (i) Speed (ii) Stator current (iii) Power factor (iv) P_{conv} and P_{out} (v) τ_{ind} and τ_{load} (vi) efficiency.

- (b) For the same motor described in Q. 8(a). Find– (23)

 - Maximum torque of this motor. At what speed and slip does it occur?
 - What is the starting torque of this motor?
 - When the rotor resistance is doubled, what is the speed at which maximum torque now occurs? What is the new starting torque of the motor?

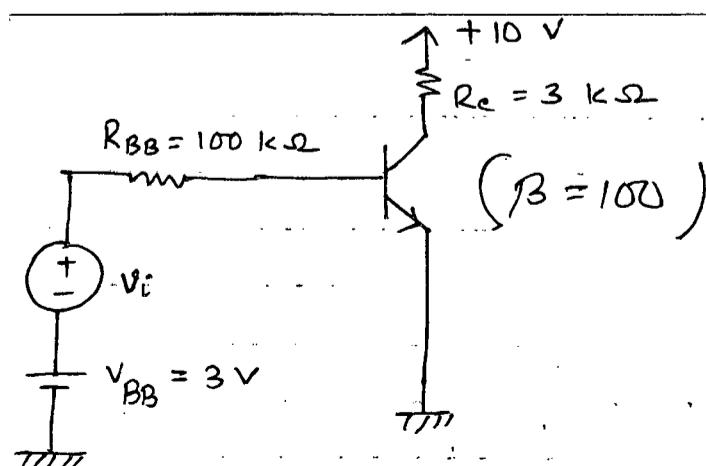
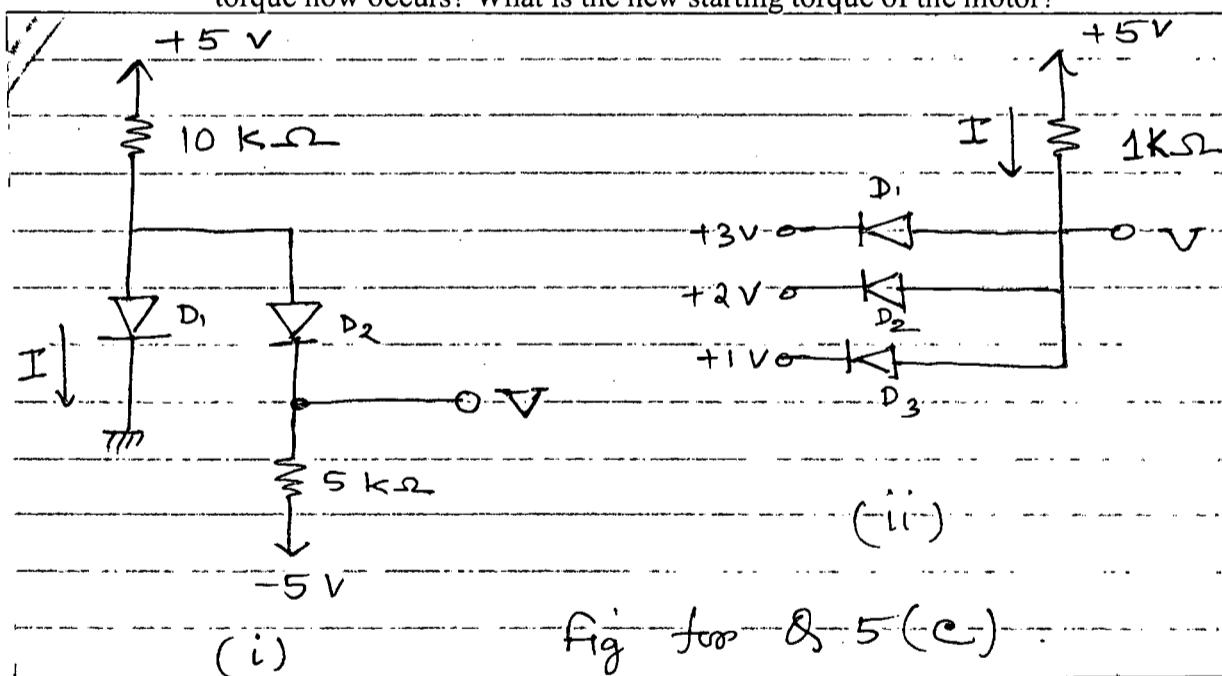


fig for g 6(c)

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2014-2015

Sub : **HUM 303** (Principles of Accounting)

Full Marks: 210

Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

SECTION – AThere are **FOUR** questions in this section. Answer any **THREE**.

1. (a) What is revenue recognition principle and expense recognition principle? Describe with examples. (5)
- (b) Marina Beach Motel has the following transaction on May, 2015: (30)
- May 1: The owner invested Tk. 100000 cash.
 May 2: Advertise in the newspaper for Tk. 5000 on account.
 May 6: Purchase supplies for cash Tk. 6000.
 May 10: Purchase furniture for Tk. 50000, paying Tk. 10000 cash and remaining on account.
 May 12: Provide service and billed client Tk. 50000.
 May 15: Withdraw cash for personal use Tk. 2000.
 May 18: Salary paid Tk. 10000.
 May 20: Paid dues on advertisement.
 May 22: Received dues on service provided in May 12.
 May 30: Service provided in cash Tk. 20000.

Required:

- (i) Prepare a tabular summary from the transactions.
- (ii) Prepare an Income statement and owner's equity statement for May 31, 2015.

2. (a) What are the limitations of trial balance? (5)
- (b) Following transactions are extracted from the first month of operation of Mr. Yasin: (20)
- August 1: Invested Tk. 100000 in the business.
 August 3: Purchase equipment costing Tk. 70000. A cash payment is made of Tk. 20000.
 August 10: Received cash for service provided Tk. 50000.
 August 15: Paid the due on equipment purchase.
 August 17: Provide service on account Tk. 10000.
 August 20: Incurred advertising expense Tk. 2000 and paid.
 August 25: Received cash for service provided on account.
 August 31: Paid salary Tk. 8000 in cash.

HUM 303

Contd... Q. No. 2(b)

Required:

- (i) Give journal entries for the month, August 31, 2015.
(ii) Prepare the cash ledger.
(c) Following are the account balances of Beacon Computer Service Company for the year ended on 30th June, 2015:

(10)

Purchasing Cost of Computer Tk. 20,00,000; Sale of computer Tk. 3400000; Service fees received Tk. 300000; Salaries to engineers Tk. 200000; Advertisement expense Tk. 50000; Office rent Tk. 60000; Maintenance expense Tk. 130000; Accounts payable Tk. 80000; Tax payable Tk. 5000; Bad debts Tk. 50000; Prepaid Insurance Tk. 50000; Office equipment Tk. 60000; Salary to staffs Tk. 85000; Banks Balance Tk. 455000; Unpaid salaries Tk. 5000; Accounts receivable Tk. 600000; Opening stock of computer Tk. 400000; Furniture Tk. 25000; Capital Tk. 600000.

Prepare a trial balance.

3. (a) What are the reasons of adjusting entry?

(5)

- (b) The trial balance of LG Electronics on January 31, 2014 is given below:

(30)

LG Electronics
Trial Balance
January 31, 2014

| | Debit (Tk.) | Credit (Tk.) |
|-------------------|--------------|--------------|
| Cash | 12800 | |
| Supplies | 2500 | |
| Prepaid Insurance | 3000 | |
| Office equipment | 5000 | |
| Notes payable | | 5000 |
| Accounts payable | | 2500 |
| Unearned revenue | | 1200 |
| Capital | | 10000 |
| Drawings | 500 | |
| Service revenue | | 10000 |
| Salary expense | 4000 | |
| Utility expense | 900 | |
| Total= | <u>28700</u> | <u>28700</u> |

Analysis reveals the following additional data;

- Supplies on hand at the end of the month Tk. 1200.
- Insurance policy is for two years.

HUM 303

Contd... Q. No. 3(b)

- Depreciation is Tk. 200 for each month.
- Unearned revenue is still unearned Tk. 800.
- Interest accrued at January Tk. 200
- Service provided but not yet recorded Tk. 1200.

Required:

- (i) Prepare necessary adjusting entries.
- (ii) Prepare an adjusted trial balance as on January 31, 2014.

4. The following is the trial balance of Harvey Company as on 31st December, 2014: (35)

| Account Title | Debit (Tk.) | Credit (Tk.) |
|----------------------------------|---------------|---------------|
| Sales revenue | | 50000 |
| Merchandise Inventory (01.01.14) | 6000 | |
| Purchase | 24000 | |
| Purchase return | | 1000 |
| Sales Discounts | 2500 | |
| Accounts Receivable | 20000 | |
| Accounts payable | | 14000 |
| Capital | | 40000 |
| Drawings | 10000 | |
| Salaries expense | 8000 | |
| Supplies | 3000 | |
| Delivery Van | 20000 | |
| Cash | 9300 | |
| Prepaid Insurance | 2200 | |
| Total= | <u>105000</u> | <u>105000</u> |

Other information:

- Supplies used Tk. 1200
- Depreciation on delivery van is Tk. 2000
- Merchandise inventory (31.12.2014) Tk. 5500.
- Tk. 2500 of accounts receivable was uncollectible.
- Salaries were accrued Tk. 4000.
- Insurance expense was Tk. 2000.

Required:

- (i) Prepare classified Income statement and Owner's equity statement for the period ended 31st December, 2014.
- (ii) Prepare a Balance Sheet as on 31st December, 2014.
- (iii) Determine profit margin ratio, Inventory turnover ratio and current ratio.

HUM 303

SECTION - B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) What is the major disadvantage of the high-low method? (5)
(b) The number of X-rays taken and X-ray costs over the last nine months in Beverly Hospital are given below: (10)

| Month | X-Rays Taken | X-Ray Costs |
|-----------|--------------|-------------|
| January | 6,250 | \$25,000 |
| February | 7,000 | \$29,000 |
| March | 5,000 | \$23,000 |
| April | 4,250 | \$20,000 |
| May | 4,500 | \$22,000 |
| June | 3,000 | \$17,000 |
| July | 3,750 | \$18,000 |
| August | 5,500 | \$24,000 |
| September | 5,750 | \$26,000 |

Required:

- (i) Using the high-low method, estimate the cost formula for X-ray costs.
(ii) Using the cost formula you derived above, what X-ray costs would you expect to be incurred during a month in which 4,600 X-rays are taken?
(c) A product sells for \$20 per unit, and has a contribution margin ratio of 40%. Fixed expenses total \$120,000 annually. How many units must be sold to yield a profit of \$30,000? (8)
(d) The following monthly data are available for the Eager Company and its only product: (12)

| | |
|-------------------------------------|---------------|
| Unit sales price | \$75 |
| Unit variable expenses | \$30 |
| Total fixed expenses | \$180,000 |
| Actual sales for the month of March | \$7,000 units |

Calculate the Break-Even-Point and Margin of Safety for the company.

6. (a) Define the following with examples: (12)
- (i) direct materials
(ii) indirect materials
(iii) direct labor
(iv) indirect labor
(v) manufacturing overhead.

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Contd... Q. No. 3

(b) The following costs relate to one month's activity in Martin Company:

(23)

| | |
|--------------------------------------|---------|
| Indirect materials | \$300 |
| Rent on factory building | \$500 |
| Maintenance of equipment | \$50 |
| Direct material used | \$1,200 |
| Utilities on factory | \$250 |
| Direct labor | \$1,500 |
| Selling expense | \$500 |
| Administrative expense | \$300 |
| Work in process inventory, beginning | \$600 |
| Work in process inventory, ending | \$800 |
| Finished goods inventory, beginning | \$500 |
| Finished goods inventory, ending | \$250 |

Required:

- (i) Prepare a Schedule of Cost of Goods Manufactured in good form.
- (ii) Determine the Cost of Goods Sold.

7. (a) What are the arguments in favor of treating fixed manufacturing overhead costs as product costs?

(5)

(b) If the units produced exceed unit sales, which method would you expect to show the higher net operating income, variable costing or absorption costing? Why?

(6)

(c) Last year, Walsh Company manufactured 25,000 units and sold 22,000 units.

Production costs were as follows:

(24)

| | |
|---------------------------------|-----------|
| Direct material | \$100,000 |
| Direct labor | \$75,000 |
| Variable manufacturing overhead | \$50,000 |
| Fixed manufacturing overhead | \$75,000 |

Sales totaled \$440,000, variable selling and administrative expenses were \$110,000, and fixed selling and administrative expenses were \$45,000. There was no beginning inventory. Assume that direct labor is a variable cost.

Required:

- (i) What is the unit product cost for the year under Variable Costing and Absorption Costing?
- (ii) What is the net income for the year under Variable Costing and Absorption Costing?

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8. (a) Explain the difference between a product cost and a period cost. (5)

(b) Each of the following items pertains to one of these companies Bedell Electronics (a manufacturing company) and Grocery Food Retailers (a merchandising company). Classify each item under appropriate cost category: Direct Material, Direct Labor, Manufacturing Overhead or Non-manufacturing Cost. (10)

| | Cost Item | Cost Category Name |
|----|---|--------------------|
| a. | Salary of Bedell Electronics President | |
| b. | Depreciation on Bedell Electronics production equipment | |
| c. | Salaries of Bedell's assembly line workers | |
| d. | Purchase of frozen food for sale to customers by Grocery Food Retailers | |
| e. | Depreciation on freezers at Grocery Food Retailers | |

(c) A company wants to purchase a new equipment. The related information of the equipment is as follows: (20)

Cost of the Equipment Tk. 70,000

| Year | NPAT (Net profit after tax) |
|------|-----------------------------|
| 1 | Tk. 40,000 |
| 2 | 13,000 |
| 3 | 20,000 |
| 4 | 10,000 |
| 5 | 7,000 |

Required:

- Determine-
- (i) Pay Back Period (PBP)
 - (ii) Internal rate of return (IRR)
 - (iii) Net present value at 10% cost of capital.

Should the company buy the equipment?

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

Property tables are supplied. Symbols indicate their usual meaning.

1. (a) Define and classify thermodynamic properties. **(6 2/3)**
 (b) Define 'heat' and 'work'. Explain the physical meaning of 'flow work'. **(10)**
 (c) Write a short note on 'thermodynamic equilibrium'. What is meant by 'quasi-static' process? **(10)**
 (d) Write short notes on **(20)**
 - (i) thermodynamic system
 - (ii) closed mass system
 - (iii) thermodynamic cycle
 - (iv) 'zero-th' law of thermodynamics
 - (v) joule free-expansion experiment.

2. (a) Using 'First-law of thermodynamics' show that 'energy' is a thermodynamic property. **(6 2/3)**
 (b) Briefly present 'energy equation for control volume system'. Using suitable assumptions, derive Bernoulli's equation from it. **(10)**
 (c) An air compressor operates at steady flow with air entering at $P_1 = 1$ bar, $T_1 = 27^\circ\text{C}$, and exiting at $P_2 = 10$ bar. If the air undergoes a polytropic process with $n = 1.33$, estimate work done and heat transfer in kJ/kg. **(10)**
 (d) With schematic diagrams and suitable assumptions, simplify the 1st law of thermodynamics for the following process: **(20)**
 - (i) nozzle
 - (ii) pump
 - (iii) heat exchanger
 - (iv) throttling

3. (a) State clausius statement of the Second Law of thermodynamics. Show that, violation of clausius statement results in the violation of Kelvin-Planck statement. **(6 2/3)**
 (b) Using Carnot's principle, present thermodynamic temperature scale. **(10)**

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Contd... Q. No. 3

(c) Present a brief second law analysis for CV system. (10)

(d) Water vapour at 5 bar, 325°C enters a steam turbine at a steady state with a volume flow rate of 1.0 m³/s and expand adiabatically to an exit state of 1 bar and 165°C.

Determine for the turbine (20)

- (i) the power developed in kW
- (ii) the rate of entropy production in kW/k
- (iii) the isentropic efficiency.

Discuss the result.

4. (a) Explain the physical meaning of heating value(s) of fuels. (6 2/3)

(b) Show that, (10)

$$C_P - C_V = -T \cdot \left(\frac{\partial p}{\partial v} \right)_T \cdot \left(\frac{\partial v}{\partial T} \right)_P^2 = \frac{\beta^2}{K_T} \cdot vT.$$

(c) Write short notes: (30)

- (i) Clausius-clapeyron equation
- (ii) Joule-Thomson coefficient
- (iii) First Tds relation
- (iv) Principle of increase of entropy
- (v) Entropy

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

Assume reasonable values for any missing data. All the symbols have their usual meaning.

5. (a) What is the physical significance of the compressibility factor Z? Under what conditions is the ideal-gas assumption suitable for steam? (13)

(b) A mixture of oxygen (O₂), carbon dioxide (CO₂), and helium (He) gases with mass fractions of 0.0625, 0.625 and 0.3125, respectively, enter an adiabatic turbine at 1000 kPa and 600 K steadily and expands to 100 kPa pressure. The isentropic efficiency of the turbine is 90%. For gas components assuming constant specific heats at room temperature, determine the work output per unit mass of the mixture. (26 2/3)

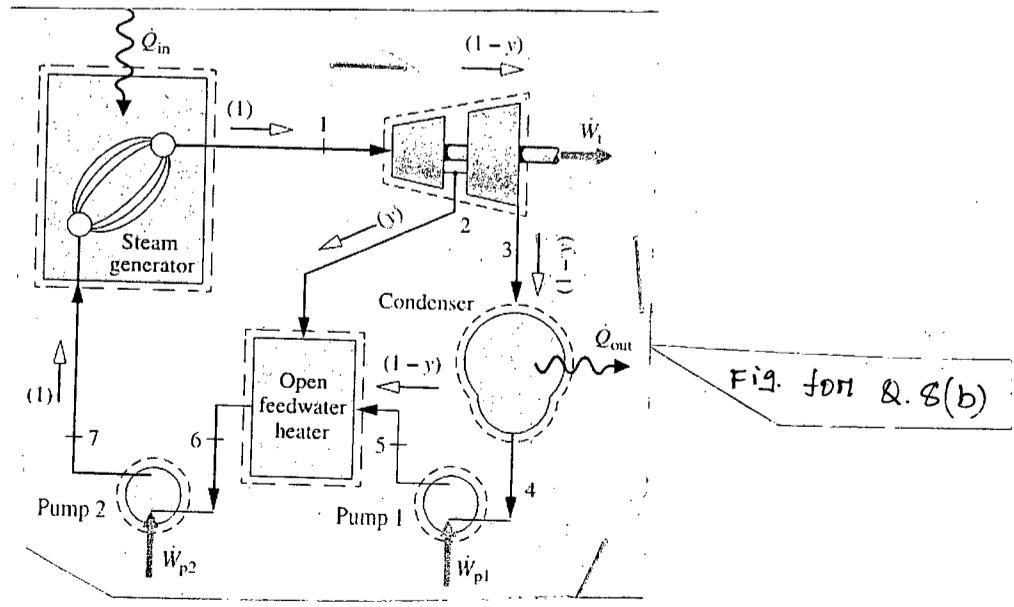
The specific heats at room temperature (25°C) are:

| | C _v (kJ/kg.k) | C _P (kJ/kg.k) |
|-------------------|--------------------------|--------------------------|
| O ₂ : | 0.658 | 0.918 |
| CO ₂ : | 0.657 | 0.846 |
| He : | 3.1156 | 5.1926 |

(c) Can the water vapor in air be treated as an ideal gas? Explain. (7)

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6. (a) Two airstreams are mixed steadily and adiabatically. The first stream enters at 32°C and 40% R.H. at a rate of $20 \text{ m}^3/\text{min}$, while the second stream enters at 12°C and 90% R.H. at a rate of $25 \text{ m}^3/\text{min}$. Assuming that the mixing process occurs at a pressure of 1 atm, determine the specific humidity, R.H., T_{db} , and T_{dp} of the mixture. (20)
- (b) Refrigerant-134a enters the compressor of a refrigerator as a superheated vapor at 0.14 MPa and -10°C at a rate of 0.05 kg/s and leaves at 0.8 MPa and 50°C . The refrigerant is cooled in the condenser to 26°C and 0.72 MPa and is throttled to 0.15 MPa . Disregarding any heat transfer and pressure drops in the connecting lines between the components, determine— $(26\frac{2}{3})$
- (i) the rate of heat removal from the refrigerated space and the power input in the compressor.
 - (ii) isentropic efficiency of the compressor.
 - (iii) COP of the refrigerator.
7. (a) Derive the equation for thermal efficiency of an ideal diesel cycle. (23)
- (b) An ideal gas-turbine cycle with two stages of compression and two stages of expansion has an overall pressure ratio 8. Air enters each stage of the compressor at 300 K and each stage of the turbine at 1300 K . Determine the back work ratio and thermal efficiency of the gas turbine. $(23\frac{2}{3})$
8. (a) What four processes make up the simple ideal Rankine cycle? Explain how can we increase the efficiency of the Rankine cycle? $(16\frac{2}{3})$
- (b) Consider a steam power plant operating on the ideal regenerative Rankine cycle with one open feed water heater. Steam enters the turbine at 15 MPa and 600°C and is condensed in the condenser at a pressure of 10 kPa . Some steam leaves the turbine at a pressure of 1.2 MPa and enters the open feed water heater. Determine the fraction of steam extracted from the turbine and the thermal efficiency of the cycle. (30)



Carrier

PSYCHROMETRIC CHART

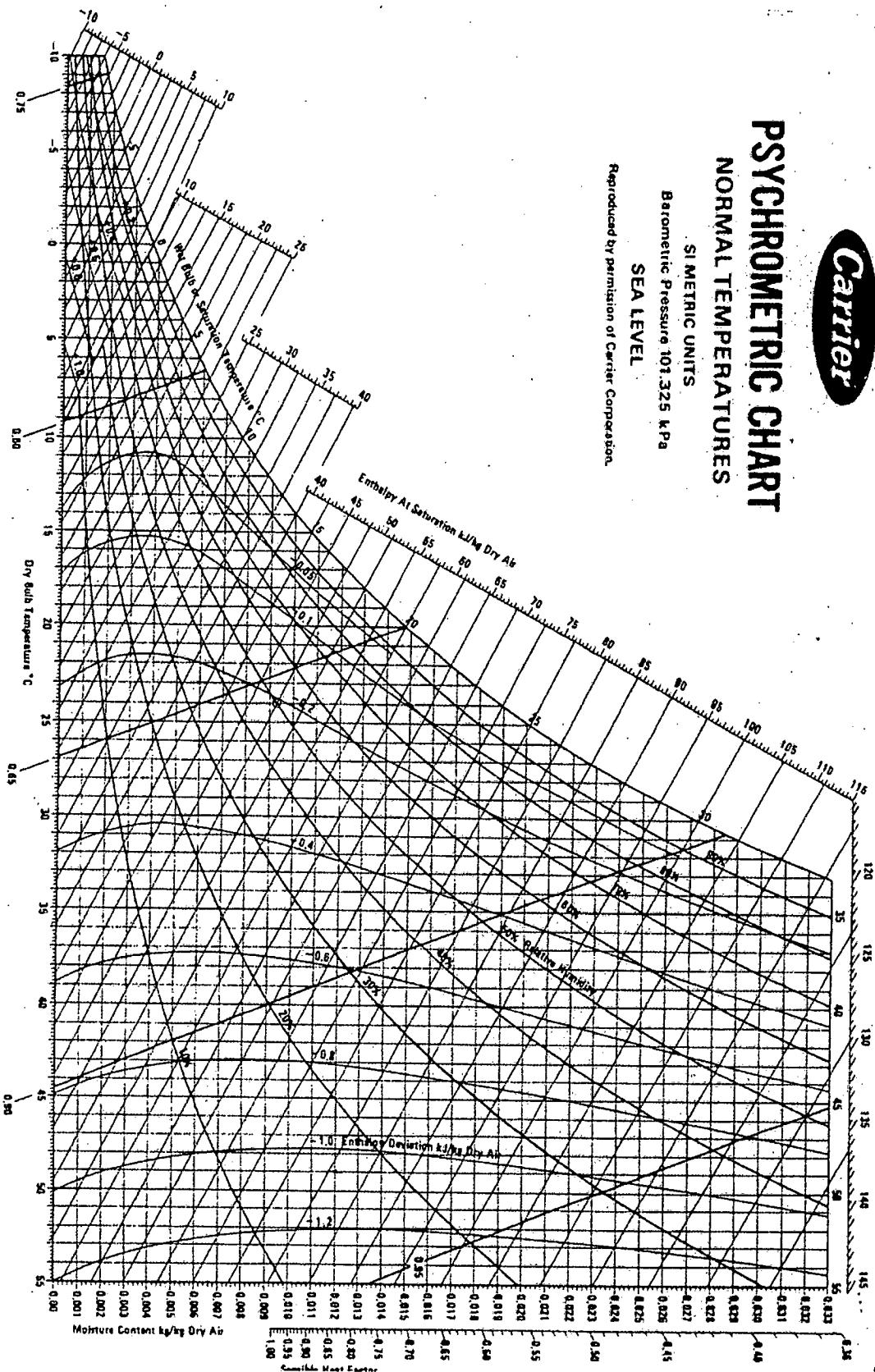
NORMAL TEMPERATURES

SI METRIC UNITS

Barometric Pressure 101.325 kPa

SEA LEVEL

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R-134a = 5 =

Properties of Saturated Refrigerant 134a (Liquid-Vapor): Temperature Table

| Temp. °C | Press. bar | Specific Volume m³/kg | | Internal Energy kJ/kg | | Enthalpy kJ/kg | | Entropy kJ/kg · K | | Temp. °C |
|-------------|---------------|-------------------------------------|------------------------|--------------------------|------------------------|-------------------------|-------------------|------------------------|-------------------------|-------------|
| | | Sat. Liquid $v_f \times 10^3$ | Sat. Vapor v_g | Sat. Liquid u_f | Sat. Vapor u_g | Sat. Liquid h_f | Evap. h_{fg} | Sat. Vapor h_g | Sat. Liquid s_f | |
| -40 | 0.5164 | 0.7055 | 0.3569 | -0.04 | 204.45 | 0.00 | 222.88 | 222.88 | 0.0000 | 0.9560 |
| -36 | 0.6332 | 0.7113 | 0.2947 | 4.68 | 206.73 | 4.73 | 220.67 | 225.40 | 0.0201 | 0.9506 |
| -32 | 0.7704 | 0.7172 | 0.2451 | 9.47 | 209.01 | 9.52 | 218.37 | 227.90 | 0.0401 | 0.9456 |
| -28 | 0.9305 | 0.7233 | 0.2052 | 14.31 | 211.29 | 14.37 | 216.01 | 230.38 | 0.0600 | 0.9411 |
| -26 | 1.0199 | 0.7265 | 0.1882 | 16.75 | 212.43 | 16.82 | 214.80 | 231.62 | 0.0699 | 0.9390 |
| -24 | 1.1160 | 0.7296 | 0.1728 | 19.21 | 213.57 | 19.29 | 213.57 | 232.85 | 0.0798 | 0.9370 |
| -22 | 1.2192 | 0.7328 | 0.1590 | 21.68 | 214.70 | 21.77 | 212.32 | 234.08 | 0.0897 | 0.9351 |
| -20 | 1.3299 | 0.7361 | 0.1464 | 24.17 | 215.84 | 24.26 | 211.05 | 235.31 | 0.0996 | 0.9332 |
| -18 | 1.4483 | 0.7395 | 0.1350 | 26.67 | 216.97 | 26.77 | 209.76 | 236.53 | 0.1094 | 0.9315 |
| -16 | 1.5748 | 0.7428 | 0.1247 | 29.18 | 218.10 | 29.30 | 208.45 | 237.74 | 0.1192 | 0.9298 |
| -12 | 1.8540 | 0.7498 | 0.1068 | 34.25 | 220.36 | 34.39 | 205.77 | 240.15 | 0.1388 | 0.9267 |
| -8 | 2.1704 | 0.7569 | 0.0919 | 39.38 | 222.60 | 39.54 | 203.00 | 242.54 | 0.1583 | 0.9239 |
| -4 | 2.5274 | 0.7644 | 0.0794 | 44.56 | 224.84 | 44.75 | 200.15 | 244.90 | 0.1777 | 0.9213 |
| 0 | 2.9282 | 0.7721 | 0.0689 | 49.79 | 227.06 | 50.02 | 197.21 | 247.23 | 0.1970 | 0.9190 |
| 4 | 3.3765 | 0.7801 | 0.0600 | 55.08 | 229.27 | 55.35 | 194.19 | 249.53 | 0.2162 | 0.9169 |
| 8 | 3.8756 | 0.7884 | 0.0525 | 60.43 | 231.46 | 60.73 | 191.07 | 251.80 | 0.2354 | 0.9150 |
| 12 | 4.4294 | 0.7971 | 0.0460 | 65.83 | 233.63 | 66.18 | 187.85 | 254.03 | 0.2545 | 0.9132 |
| 16 | 5.0416 | 0.8062 | 0.0405 | 71.29 | 235.78 | 71.69 | 184.52 | 256.22 | 0.2735 | 0.9116 |
| 20 | 5.7160 | 0.8157 | 0.0358 | 76.80 | 237.91 | 77.26 | 181.09 | 258.36 | 0.2924 | 0.9102 |
| 24 | 6.4566 | 0.8257 | 0.0317 | 82.37 | 240.01 | 82.90 | 177.55 | 260.45 | 0.3113 | 0.9089 |
| 26 | 6.8530 | 0.8309 | 0.0298 | 85.18 | 241.05 | 85.75 | 175.73 | 261.48 | 0.3208 | 0.9082 |
| 28 | 7.2675 | 0.8362 | 0.0281 | 88.00 | 242.08 | 88.61 | 173.89 | 262.50 | 0.3302 | 0.9076 |
| 30 | 7.7006 | 0.8417 | 0.0265 | 90.84 | 243.10 | 91.49 | 172.00 | 263.50 | 0.3396 | 0.9070 |
| 32 | 8.1528 | 0.8473 | 0.0250 | 93.70 | 244.12 | 94.39 | 170.09 | 264.48 | 0.3490 | 0.9064 |
| 34 | 8.6247 | 0.8530 | 0.0236 | 96.58 | 245.12 | 97.31 | 168.14 | 265.45 | 0.3584 | 0.9058 |
| 36 | 9.1168 | 0.8590 | 0.0223 | 99.47 | 246.11 | 100.25 | 166.15 | 266.40 | 0.3678 | 0.9053 |
| 38 | 9.6298 | 0.8651 | 0.0210 | 102.38 | 247.09 | 103.21 | 164.12 | 267.33 | 0.3772 | 0.9047 |
| 40 | 10.164 | 0.8714 | 0.0199 | 105.30 | 248.06 | 106.19 | 162.05 | 268.24 | 0.3866 | 0.9041 |
| 42 | 10.720 | 0.8780 | 0.0188 | 108.25 | 249.02 | 109.19 | 159.94 | 269.14 | 0.3960 | 0.9035 |
| 44 | 11.299 | 0.8847 | 0.0177 | 111.22 | 249.96 | 112.22 | 157.79 | 270.01 | 0.4054 | 0.9030 |
| 48 | 12.526 | 0.8989 | 0.0159 | 117.22 | 251.79 | 118.35 | 153.33 | 271.68 | 0.4243 | 0.9017 |
| 52 | 13.851 | 0.9142 | 0.0142 | 123.31 | 253.55 | 124.58 | 148.66 | 273.24 | 0.4432 | 0.9004 |
| 56 | 15.278 | 0.9308 | 0.0127 | 129.51 | 255.23 | 130.93 | 143.75 | 274.68 | 0.4622 | 0.8990 |
| 60 | 16.813 | 0.9488 | 0.0114 | 135.82 | 256.81 | 137.42 | 138.57 | 275.99 | 0.4814 | 0.8973 |
| 70 | 21.162 | 1.0027 | 0.0086 | 152.22 | 260.15 | 154.34 | 124.08 | 278.43 | 0.5302 | 0.8918 |
| 80 | 26.324 | 1.0766 | 0.0064 | 169.88 | 262.14 | 172.71 | 106.41 | 279.12 | 0.5814 | 0.8827 |
| 90 | 32.435 | 1.1949 | 0.0046 | 189.82 | 261.34 | 193.69 | 82.63 | 276.32 | 0.6380 | 0.8655 |
| 100 | 39.742 | 1.5443 | 0.0027 | 218.60 | 248.49 | 224.74 | 34.40 | 259.13 | 0.7196 | 0.8117 |

Source: Tables A-10 through A-12 are calculated based on equations from D. P. Wilson and R. S. Basu, "Thermodynamic Properties of a New Stratospherically Safe Working Fluid—Refrigerant 134a," ASHRAE Trans., Vol. 94, Pt. 2, 1988, pp. 2095–2118.

Properties of Saturated Refrigerant 134a (Liquid-Vapor): Pressure Table

| Press. bar | Temp. °C | Specific Volume m³/kg | | Internal Energy kJ/kg | | Enthalpy kJ/kg | | Entropy kJ/kg · K | | Press. bar |
|---------------|-------------|-------------------------------------|------------------------|--------------------------|------------------------|-------------------------|-------------------|------------------------|-------------------------|---------------|
| | | Sat. Liquid $v_f \times 10^3$ | Sat. Vapor v_g | Sat. Liquid u_f | Sat. Vapor u_g | Sat. Liquid h_f | Evap. h_{fg} | Sat. Vapor h_g | Sat. Liquid s_f | |
| 0.6 | -37.07 | 0.7097 | 0.3100 | 3.41 | 206.12 | 3.46 | 221.27 | 224.72 | 0.0147 | 0.9520 |
| 0.8 | -31.21 | 0.7184 | 0.2366 | 10.41 | 209.46 | 10.47 | 217.92 | 228.39 | 0.0440 | 0.9447 |
| 1.0 | -26.43 | 0.7258 | 0.1917 | 16.22 | 212.18 | 16.29 | 215.06 | 231.35 | 0.0678 | 0.9395 |
| 1.2 | -22.36 | 0.7323 | 0.1614 | 21.23 | 214.50 | 21.32 | 212.54 | 233.86 | 0.0879 | 0.9354 |
| 1.4 | -18.80 | 0.7381 | 0.1395 | 25.66 | 216.52 | 25.77 | 210.27 | 236.04 | 0.1055 | 0.9322 |
| 1.6 | -15.62 | 0.7435 | 0.1229 | 29.66 | 218.32 | 29.78 | 208.19 | 237.97 | 0.1211 | 0.9295 |
| 1.8 | -12.73 | 0.7485 | 0.1098 | 33.31 | 219.94 | 33.45 | 206.26 | 239.71 | 0.1352 | 0.9273 |
| 2.0 | -10.09 | 0.7532 | 0.0993 | 36.69 | 221.43 | 36.84 | 204.46 | 241.30 | 0.1481 | 0.9253 |
| 2.4 | -5.37 | 0.7618 | 0.0834 | 42.77 | 224.07 | 42.95 | 201.14 | 244.09 | 0.1710 | 0.9222 |
| 2.8 | -1.23 | 0.7697 | 0.0719 | 48.18 | 226.38 | 48.39 | 198.13 | 246.52 | 0.1911 | 0.9197 |
| 3.2 | 2.48 | 0.7770 | 0.0632 | 53.06 | 228.43 | 53.31 | 195.35 | 248.66 | 0.2089 | 0.9177 |
| 3.6 | 5.84 | 0.7839 | 0.0564 | 57.54 | 230.28 | 57.82 | 192.76 | 250.58 | 0.2251 | 0.9160 |
| 4.0 | 8.93 | 0.7904 | 0.0509 | 61.69 | 231.97 | 62.00 | 190.32 | 252.32 | 0.2399 | 0.9145 |
| 5.0 | 15.74 | 0.8056 | 0.0409 | 70.93 | 235.64 | 71.33 | 184.74 | 256.07 | 0.2723 | 0.9117 |
| 6.0 | 21.58 | 0.8196 | 0.0341 | 78.99 | 238.74 | 79.48 | 179.71 | 259.19 | 0.2999 | 0.9097 |
| 7.0 | 26.72 | 0.8328 | 0.0292 | 86.19 | 241.42 | 86.78 | 175.07 | 261.85 | 0.3242 | 0.9080 |
| 8.0 | 31.33 | 0.8454 | 0.0255 | 92.75 | 243.78 | 93.42 | 170.73 | 264.15 | 0.3459 | 0.9066 |
| 9.0 | 35.53 | 0.8576 | 0.0226 | 98.79 | 245.88 | 99.56 | 166.62 | 266.18 | 0.3656 | 0.9054 |
| 10.0 | 39.39 | 0.8695 | 0.0202 | 104.42 | 247.77 | 105.29 | 162.68 | 267.97 | 0.3838 | 0.9043 |
| 12.0 | 46.32 | 0.8928 | 0.0166 | 114.69 | 251.03 | 115.76 | 155.23 | 270.99 | 0.4164 | 0.9023 |
| 14.0 | 52.43 | 0.9159 | 0.0140 | 123.98 | 253.74 | 125.26 | 148.14 | 273.40 | 0.4453 | 0.9003 |
| 16.0 | 57.92 | 0.9392 | 0.0121 | 132.52 | 256.00 | 134.02 | 141.31 | 275.33 | 0.4714 | 0.8982 |
| 18.0 | 62.91 | 0.9631 | 0.0105 | 140.49 | 257.88 | 142.22 | 134.60 | 276.83 | 0.4954 | 0.8959 |
| 20.0 | 67.49 | 0.9878 | 0.0093 | 148.02 | 259.41 | 149.99 | 127.95 | 277.94 | 0.5178 | 0.8934 |
| 25.0 | 77.59 | 1.0562 | 0.0069 | 165.48 | 261.84 | 168.12 | 111.06 | 279.17 | 0.5687 | 0.8854 |
| 30.0 | 86.22 | 1.1416 | 0.0053 | 181.88 | 262.16 | 185.30 | 92.71 | 278.01 | 0.6156 | 0.8735 |

R-134a

Properties of Superheated Refrigerant 134a Vapor

| T °C | v m³/kg | u kJ/kg | h kJ/kg | s kJ/kg · K | v m³/kg | u kJ/kg | h kJ/kg | s kJ/kg · K |
|---|------------|------------|------------|----------------|------------|------------|------------|----------------|
| $p = 0.6 \text{ bar} = 0.06 \text{ MPa}$ ($T_{\text{sat}} = -37.07^\circ\text{C}$) | | | | | | | | |
| $p = 1.0 \text{ bar} = 0.10 \text{ MPa}$ ($T_{\text{sat}} = -26.43^\circ\text{C}$) | | | | | | | | |
| Sat. | 0.31003 | 206.12 | 224.72 | 0.9520 | 0.19170 | 212.18 | 231.35 | 0.9395 |
| -20 | 0.33536 | 217.86 | 237.98 | 1.0062 | 0.19770 | 216.77 | 236.54 | 0.9602 |
| -10 | 0.34992 | 224.97 | 245.96 | 1.0371 | 0.20686 | 224.01 | 244.70 | 0.9918 |
| 0 | 0.36433 | 232.24 | 254.10 | 1.0675 | 0.21587 | 231.41 | 252.99 | 1.0227 |
| 10 | 0.37861 | 239.69 | 262.41 | 1.0973 | 0.22473 | 238.96 | 261.43 | 1.0531 |
| 20 | 0.39279 | 247.32 | 270.89 | 1.1267 | 0.23349 | 246.67 | 270.02 | 1.0829 |
| 30 | 0.40688 | 255.12 | 279.53 | 1.1557 | 0.24216 | 254.54 | 278.76 | 1.1122 |
| 40 | 0.42091 | 263.10 | 288.35 | 1.1844 | 0.25076 | 262.58 | 287.66 | 1.1411 |
| 50 | 0.43487 | 271.25 | 297.34 | 1.2126 | 0.25930 | 270.79 | 296.72 | 1.1696 |
| 60 | 0.44879 | 279.58 | 306.51 | 1.2405 | 0.26779 | 279.16 | 305.94 | 1.1977 |
| 70 | 0.46266 | 288.08 | 315.84 | 1.2681 | 0.27623 | 287.70 | 315.32 | 1.2254 |
| 80 | 0.47650 | 296.75 | 325.34 | 1.2954 | 0.28464 | 296.40 | 324.87 | 1.2528 |
| 90 | 0.49031 | 305.58 | 335.00 | 1.3224 | 0.29302 | 305.27 | 334.57 | 1.2799 |

$p = 1.4 \text{ bar} = 0.14 \text{ MPa}$
($T_{\text{sat}} = -18.80^\circ\text{C}$)

| | | | | |
|------|---------|--------|--------|--------|
| Sat. | 0.13945 | 216.52 | 236.04 | 0.9322 |
| -10 | 0.14549 | 223.03 | 243.40 | 0.9606 |
| 0 | 0.15219 | 230.55 | 251.86 | 0.9922 |
| 10 | 0.15875 | 238.21 | 260.43 | 1.0230 |
| 20 | 0.16520 | 246.01 | 269.13 | 1.0532 |
| 30 | 0.17155 | 253.96 | 277.97 | 1.0828 |
| 40 | 0.17783 | 262.06 | 286.96 | 1.1120 |
| 50 | 0.18404 | 270.32 | 296.09 | 1.1407 |
| 60 | 0.19020 | 278.74 | 305.37 | 1.1690 |
| 70 | 0.19633 | 287.32 | 314.80 | 1.1969 |
| 80 | 0.20241 | 296.06 | 324.39 | 1.2244 |
| 90 | 0.20846 | 304.95 | 334.14 | 1.2516 |
| 100 | 0.21449 | 314.01 | 344.04 | 1.2785 |

$p = 1.8 \text{ bar} = 0.18 \text{ MPa}$
($T_{\text{sat}} = -12.73^\circ\text{C}$)

| | | | | |
|------|---------|--------|--------|--------|
| Sat. | 0.10983 | 219.94 | 239.71 | 0.9273 |
| -10 | 0.11135 | 222.02 | 242.06 | 0.9362 |
| 0 | 0.11678 | 229.67 | 250.69 | 0.9684 |
| 10 | 0.12207 | 237.44 | 259.41 | 0.9998 |
| 20 | 0.12723 | 245.33 | 268.23 | 1.0304 |
| 30 | 0.13230 | 253.36 | 277.17 | 1.0604 |
| 40 | 0.13730 | 261.53 | 286.24 | 1.0898 |
| 50 | 0.14222 | 269.85 | 295.45 | 1.1187 |
| 60 | 0.14710 | 278.31 | 304.79 | 1.1472 |
| 70 | 0.15193 | 286.93 | 314.28 | 1.1753 |
| 80 | 0.15672 | 295.71 | 323.92 | 1.2030 |
| 90 | 0.16148 | 304.63 | 333.70 | 1.2303 |
| 100 | 0.16622 | 313.72 | 343.63 | 1.2573 |

$p = 2.0 \text{ bar} = 0.20 \text{ MPa}$
($T_{\text{sat}} = -10.09^\circ\text{C}$)

| | | | | |
|------|---------|--------|--------|--------|
| Sat. | 0.09933 | 221.43 | 241.30 | 0.9253 |
| -10 | 0.09938 | 221.50 | 241.38 | 0.9256 |
| 0 | 0.10438 | 229.23 | 250.10 | 0.9582 |
| 10 | 0.10922 | 237.05 | 258.89 | 0.9898 |
| 20 | 0.11394 | 244.99 | 267.78 | 1.0206 |
| 30 | 0.11856 | 253.06 | 276.77 | 1.0508 |
| 40 | 0.12311 | 261.26 | 285.88 | 1.0804 |
| 50 | 0.12758 | 269.61 | 295.12 | 1.1094 |
| 60 | 0.13201 | 278.10 | 304.50 | 1.1380 |
| 70 | 0.13639 | 286.74 | 314.02 | 1.1661 |
| 80 | 0.14073 | 295.53 | 323.68 | 1.1939 |
| 90 | 0.14504 | 304.47 | 333.48 | 1.2212 |
| 100 | 0.14932 | 313.57 | 343.43 | 1.2483 |

$p = 2.4 \text{ bar} = 0.24 \text{ MPa}$
($T_{\text{sat}} = -5.37^\circ\text{C}$)

| | | | | |
|------|---------|--------|--------|--------|
| Sat. | 0.08343 | 224.07 | 244.09 | 0.9222 |
| -10 | 0.08574 | 228.31 | 248.89 | 0.9399 |
| 0 | 0.08993 | 236.26 | 257.84 | 0.9721 |
| 10 | 0.09399 | 244.30 | 266.85 | 1.0034 |
| 20 | 0.09794 | 252.45 | 275.95 | 1.0339 |
| 30 | 0.10181 | 260.72 | 285.16 | 1.0637 |
| 40 | 0.10562 | 269.12 | 294.47 | 1.0930 |
| 50 | 0.10937 | 277.67 | 303.91 | 1.1218 |
| 60 | 0.11307 | 286.35 | 313.49 | 1.1501 |
| 70 | 0.11674 | 295.18 | 323.19 | 1.1780 |
| 80 | 0.12037 | 304.15 | 333.04 | 1.2055 |
| 90 | 0.12398 | 313.27 | 343.03 | 1.2326 |

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(Continued)

| T °C | v m³/kg | u kJ/kg | h kJ/kg | s kJ/kg · K | v m³/kg | u kJ/kg | h kJ/kg | s kJ/kg · K |
|--|------------|------------|------------|----------------|------------|------------|------------|----------------|
| $p = 2.8 \text{ bar} = 0.28 \text{ MPa}$ ($T_{\text{sat}} = -1.23^\circ\text{C}$) | | | | | | | | |
| $p = 3.2 \text{ bar} = 0.32 \text{ MPa}$ ($T_{\text{sat}} = 2.48^\circ\text{C}$) | | | | | | | | |
| Sat. | 0.07193 | 226.38 | 246.52 | 0.9197 | 0.06322 | 228.43 | 248.66 | 0.9177 |
| 0 | 0.07240 | 227.37 | 247.64 | 0.9238 | 0.06576 | 234.61 | 255.65 | 0.9427 |
| 10 | 0.07613 | 235.44 | 256.76 | 0.9566 | 0.06901 | 242.87 | 264.95 | 0.9749 |
| 20 | 0.07972 | 243.59 | 265.91 | 0.9883 | 0.07214 | 251.19 | 274.28 | 1.0062 |
| 30 | 0.08320 | 251.83 | 275.12 | 1.0192 | 0.07518 | 259.61 | 283.67 | 1.0367 |
| 40 | 0.08660 | 260.17 | 284.42 | 1.0494 | 0.07815 | 268.14 | 293.15 | 1.0665 |
| 50 | 0.08992 | 268.64 | 293.81 | 1.0789 | 0.08106 | 276.79 | 302.72 | 1.0957 |
| 60 | 0.09319 | 277.23 | 303.32 | 1.1079 | 0.08392 | 285.56 | 312.41 | 1.1243 |
| 70 | 0.09641 | 285.96 | 312.95 | 1.1364 | 0.08674 | 294.46 | 322.22 | 1.1525 |
| 80 | 0.09960 | 294.82 | 322.71 | 1.1644 | 0.08953 | 303.50 | 332.15 | 1.1802 |
| 90 | 0.10275 | 303.83 | 332.60 | 1.1920 | 0.09229 | 312.68 | 342.21 | 1.2076 |
| 100 | 0.10587 | 312.98 | 342.62 | 1.2193 | 0.09503 | 322.00 | 352.40 | 1.2345 |
| 110 | 0.10897 | 322.27 | 352.78 | 1.2461 | 0.09774 | 331.45 | 362.73 | 1.2611 |
| 120 | 0.11205 | 331.71 | 363.08 | 1.2727 | | | | |

$p = 4.0 \text{ bar} = 0.40 \text{ MPa}$
($T_{\text{sat}} = 8.93^\circ\text{C}$)

| | | | | |
|------|---------|--------|--------|--------|
| Sat. | 0.05089 | 231.97 | 252.32 | 0.9145 |
| 10 | 0.05119 | 232.87 | 253.35 | 0.9182 |
| 20 | 0.05397 | 241.37 | 262.96 | 0.9515 |
| 30 | 0.05662 | 249.89 | 272.54 | 0.9837 |
| 40 | 0.05917 | 258.47 | 282.14 | 1.0148 |
| 50 | 0.06164 | 267.13 | 291.79 | 1.0452 |
| 60 | 0.06405 | 275.89 | 301.51 | 1.0748 |
| 70 | 0.06641 | 284.75 | 311.32 | 1.1038 |
| 80 | 0.06873 | 293.73 | 321.23 | 1.1322 |
| 90 | 0.07102 | 302.84 | 331.25 | 1.1602 |
| 100 | 0.07327 | 312.07 | 341.38 | 1.1878 |
| 110 | 0.07550 | 321.44 | 351.64 | 1.2149 |
| 120 | 0.07771 | 330.94 | 362.03 | 1.2417 |
| 130 | 0.07991 | 340.58 | 372.54 | 1.2681 |
| 140 | 0.08208 | 350.35 | 383.18 | 1.2941 |

$p = 5.0 \text{ bar} = 0.50 \text{ MPa}$
($T_{\text{sat}} = 15.74^\circ\text{C}$)

| |
|----------|
| Sat.</td |
|----------|

| $p = 6.0 \text{ bar} = 0.60 \text{ MPa}$ ($T_{\text{sat}} = 21.58^\circ\text{C}$) | | | | | $p = 7.0 \text{ bar} = 0.70 \text{ MPa}$ ($T_{\text{sat}} = 26.72^\circ\text{C}$) | | | | |
|--|---------|--------|--------|--------|--|--------|--------|--------|--|
| Sat. | 0.03408 | 238.74 | 259.19 | 0.9097 | 0.02918 | 241.42 | 261.85 | 0.9080 | |
| 30 | 0.03581 | 246.41 | 267.89 | 0.9388 | 0.02979 | 244.51 | 265.37 | 0.9197 | |
| 40 | 0.03774 | 255.45 | 278.09 | 0.9719 | 0.03157 | 253.83 | 275.93 | 0.9539 | |
| 50 | 0.03958 | 264.48 | 288.23 | 1.0037 | 0.03324 | 263.08 | 286.35 | 0.9867 | |
| 60 | 0.04134 | 273.54 | 298.35 | 1.0346 | 0.03482 | 272.31 | 296.69 | 1.0182 | |
| 70 | 0.04304 | 282.66 | 308.48 | 1.0645 | 0.03634 | 281.57 | 307.01 | 1.0487 | |
| 80 | 0.04469 | 291.86 | 318.67 | 1.0938 | 0.03781 | 290.88 | 317.35 | 1.0784 | |
| 90 | 0.04631 | 301.14 | 328.93 | 1.1225 | 0.03924 | 300.27 | 327.74 | 1.1074 | |
| 100 | 0.04790 | 310.53 | 339.27 | 1.1505 | 0.04064 | 309.74 | 338.19 | 1.1358 | |
| 110 | 0.04946 | 320.03 | 349.70 | 1.1781 | 0.04201 | 319.31 | 348.71 | 1.1637 | |
| 120 | 0.05099 | 329.64 | 360.24 | 1.2053 | 0.04335 | 328.98 | 359.33 | 1.1910 | |
| 130 | 0.05251 | 339.38 | 370.88 | 1.2320 | 0.04468 | 338.76 | 370.04 | 1.2179 | |
| 140 | 0.05402 | 349.23 | 381.64 | 1.2584 | 0.04599 | 348.66 | 380.86 | 1.2444 | |
| 150 | 0.05550 | 359.21 | 392.52 | 1.2844 | 0.04729 | 358.68 | 391.79 | 1.2706 | |
| 160 | 0.05698 | 369.32 | 403.51 | 1.3100 | 0.04857 | 368.82 | 402.82 | 1.2963 | |

(Continued)

| T | v | u | h | s | v | u | h | s |
|--|------------------------|----------------|----------------|-------------------------------|------------------------|----------------|--|-------------------------------|
| $^\circ\text{C}$ | m^3/kg | kJ/kg | kJ/kg | $\text{kJ/kg} \cdot \text{K}$ | m^3/kg | kJ/kg | kJ/kg | $\text{kJ/kg} \cdot \text{K}$ |
| $p = 8.0 \text{ bar} = 0.80 \text{ MPa}$ ($T_{\text{sat}} = 31.33^\circ\text{C}$) | | | | | | | $p = 9.0 \text{ bar} = 0.90 \text{ MPa}$ ($T_{\text{sat}} = 35.53^\circ\text{C}$) | |
| Sat. | 0.02547 | 243.78 | 264.15 | 0.9066 | 0.02255 | 245.88 | 266.18 | 0.9054 |
| 40 | 0.02691 | 252.13 | 273.66 | 0.9374 | 0.02325 | 250.32 | 271.25 | 0.9217 |
| 50 | 0.02846 | 261.62 | 284.39 | 0.9711 | 0.02472 | 260.09 | 282.34 | 0.9566 |
| 60 | 0.02992 | 271.04 | 294.98 | 1.0034 | 0.02609 | 269.72 | 293.21 | 0.9897 |
| 70 | 0.03131 | 280.45 | 305.50 | 1.0345 | 0.02738 | 279.30 | 303.94 | 1.0214 |
| 80 | 0.03264 | 289.89 | 316.00 | 1.0647 | 0.02861 | 288.87 | 314.62 | 1.0521 |
| 90 | 0.03393 | 299.37 | 326.52 | 1.0940 | 0.02980 | 298.46 | 325.28 | 1.0819 |
| 100 | 0.03519 | 308.93 | 337.08 | 1.1227 | 0.03095 | 308.11 | 335.96 | 1.1109 |
| 110 | 0.03642 | 318.57 | 347.71 | 1.1508 | 0.03207 | 317.82 | 346.68 | 1.1392 |
| 120 | 0.03762 | 328.31 | 358.40 | 1.1784 | 0.03316 | 327.62 | 357.47 | 1.1670 |
| 130 | 0.03881 | 338.14 | 369.19 | 1.2055 | 0.03423 | 337.52 | 368.33 | 1.1943 |
| 140 | 0.03997 | 348.09 | 380.07 | 1.2321 | 0.03529 | 347.51 | 379.27 | 1.2211 |
| 150 | 0.04113 | 358.15 | 391.05 | 1.2584 | 0.03633 | 357.61 | 390.31 | 1.2475 |
| 160 | 0.04227 | 368.32 | 402.14 | 1.2843 | 0.03736 | 367.82 | 401.44 | 1.2735 |
| 170 | 0.04340 | 378.61 | 413.33 | 1.3098 | 0.03838 | 378.14 | 412.68 | 1.2992 |
| 180 | 0.04452 | 389.02 | 424.63 | 1.3351 | 0.03939 | 388.57 | 424.02 | 1.3245 |

| T | v | u | h | s | v | u | h | s |
|---|------------------------|----------------|----------------|-------------------------------|------------------------|----------------|---|-------------------------------|
| $^\circ\text{C}$ | m^3/kg | kJ/kg | kJ/kg | $\text{kJ/kg} \cdot \text{K}$ | m^3/kg | kJ/kg | kJ/kg | $\text{kJ/kg} \cdot \text{K}$ |
| $p = 10.0 \text{ bar} = 1.00 \text{ MPa}$ ($T_{\text{sat}} = 39.39^\circ\text{C}$) | | | | | | | $p = 12.0 \text{ bar} = 1.20 \text{ MPa}$ ($T_{\text{sat}} = 46.32^\circ\text{C}$) | |
| Sat. | 0.02020 | 247.77 | 267.97 | 0.9043 | 0.01663 | 251.03 | 270.99 | 0.9023 |
| 40 | 0.02029 | 248.39 | 268.68 | 0.9066 | 0.01712 | 254.98 | 275.52 | 0.9164 |
| 50 | 0.02171 | 258.48 | 280.19 | 0.9428 | 0.01835 | 265.42 | 287.44 | 0.9527 |
| 60 | 0.02301 | 268.35 | 291.36 | 0.9768 | 0.01947 | 275.59 | 298.96 | 0.9868 |
| 70 | 0.02423 | 278.11 | 302.34 | 1.0093 | 0.02051 | 285.62 | 310.24 | 1.0192 |
| 80 | 0.02538 | 287.82 | 313.20 | 1.0405 | 0.02150 | 295.59 | 321.39 | 1.0503 |
| 90 | 0.02649 | 297.53 | 324.01 | 1.0707 | 0.02244 | 305.54 | 332.47 | 1.0804 |
| 100 | 0.02755 | 307.27 | 334.82 | 1.1000 | 0.02335 | 315.50 | 343.52 | 1.1096 |
| 110 | 0.02858 | 317.06 | 345.65 | 1.1286 | 0.02423 | 325.51 | 354.58 | 1.1381 |
| 120 | 0.02959 | 326.93 | 356.52 | 1.1567 | 0.02508 | 335.58 | 365.68 | 1.1660 |
| 130 | 0.03058 | 336.88 | 367.46 | 1.1841 | 0.02592 | 345.73 | 376.83 | 1.1933 |
| 140 | 0.03154 | 346.92 | 378.46 | 1.2111 | 0.02674 | 355.95 | 388.04 | 1.2201 |
| 150 | 0.03250 | 357.06 | 389.56 | 1.2376 | 0.02754 | 366.27 | 399.33 | 1.2465 |
| 160 | 0.03344 | 367.31 | 400.74 | 1.2638 | 0.02834 | 376.69 | 410.70 | 1.2724 |
| 170 | 0.03436 | 377.66 | 412.02 | 1.2895 | 0.02912 | 387.21 | 422.16 | 1.2980 |

| T | v | u | h | s | v | u | h | s |
|---|------------------------|----------------|----------------|-------------------------------|------------------------|----------------|---|-------------------------------|
| $^\circ\text{C}$ | m^3/kg | kJ/kg | kJ/kg | $\text{kJ/kg} \cdot \text{K}$ | m^3/kg | kJ/kg | kJ/kg | $\text{kJ/kg} \cdot \text{K}$ |
| $p = 14.0 \text{ bar} = 1.40 \text{ MPa}$ ($T_{\text{sat}} = 52.43^\circ\text{C}$) | | | | | | | $p = 16.0 \text{ bar} = 1.60 \text{ MPa}$ ($T_{\text{sat}} = 57.92^\circ\text{C}$) | |
| Sat. | 0.01405 | 253.74 | 273.40 | 0.9003 | 0.01208 | 256.00 | 275.33 | 0.8982 |
| 60 | 0.01495 | 262.17 | 283.10 | 0.9297 | 0.01233 | 258.48 | 278.20 | 0.9069 |
| 70 | 0.01603 | 272.87 | 295.31 | 0.9658 | 0.01340 | 269.89 | 291.33 | 0.9457 |
| 80 | 0.01701 | 283.29 | 307.10 | 0.9997 | 0.01435 | 280.78 | 303.74 | 0.9813 |
| 90 | 0.01792 | 293.55 | 318.63 | 1.0319 | 0.01521 | 291.39 | 315.72 | 1.0148 |
| 100 | 0.01878 | 303.73 | 330.02 | 1.0628 | 0.01601 | 301.84 | 327.46 | 1.0467 |
| 110 | 0.01960 | 313.88 | 341.32 | 1.0927 | 0.01677 | 312.20 | 339.04 | 1.0773 |
| 120 | 0.02039 | 324.05 | 352.59 | 1.1218 | 0.01750 | 322.53 | 350.53 | 1.1069 |
| 130 | 0.02115 | 334.25 | 363.86 | 1.1501 | 0.01820 | 332.87 | 361.99 | 1.1357 |
| 140 | 0.02189 | 344.50 | 375.15 | 1.1777 | 0.01887 | 343.24 | 373.44 | 1.1638 |
| 150 | 0.02262 | 354.82 | 386.49 | 1.2048 | 0.01953 | 353.66 | 384.91 | 1.1912 |
| 160 | 0.02333 | 365.22 | 397.89 | 1.2315 | 0.02017 | 364.15 | 396.43 | 1.2181 |
| 170 | 0.02403 | 375.71 | 409.36 | 1.2576 | 0.02080 | 374.71 | 407.99 | 1.2445 |
| 180 | 0.02472 | 386.29 | 420.90 | 1.2834 | 0.02142 | 385.35 | 419.62 | 1.2704 |
| 190 | 0.02541 | 396.96 | 432.53 | 1.3088 | 0.02203 | 396.08 | 431.33 | 1.2960 |
| 200 | 0.02608 | 407.73 | 444.24 | 1.3338 | 0.02263 | 406.90 | 443.11 | 1.3212 |

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Water

Tables in SI Units

Properties of Saturated Water (Liquid-Vapor): Temperature Table

| Temp. °C | Press. bar | Specific Volume m³/kg | | Internal Energy kJ/kg | | Enthalpy kJ/kg | | | Entropy kJ/kg · K | | Temp. °C |
|-------------|---------------|-------------------------------------|------------------------|--------------------------|------------------------|-------------------------|-------------------|------------------------|-------------------------|------------------------|-------------|
| | | Sat. Liquid $v_f \times 10^3$ | Sat. Vapor v_g | Sat. Liquid u_f | Sat. Vapor u_g | Sat. Liquid h_f | Evap. h_{fg} | Sat. Vapor h_g | Sat. Liquid s_f | Sat. Vapor s_g | |
| .01 | 0.00611 | 1.0002 | 206.136 | 0.00 | 2375.3 | 0.01 | 2501.3 | 2501.4 | 0.0000 | 9.1562 | .01 |
| 4 | 0.00813 | 1.0001 | 157.232 | 16.77 | 2380.9 | 16.78 | 2491.9 | 2508.7 | 0.0610 | 9.0514 | 4 |
| 5 | 0.00872 | 1.0001 | 147.120 | 20.97 | 2382.3 | 20.98 | 2489.6 | 2510.6 | 0.0761 | 9.0257 | 5 |
| 6 | 0.00935 | 1.0001 | 137.734 | 25.19 | 2383.6 | 25.20 | 2487.2 | 2512.4 | 0.0912 | 9.0003 | 6 |
| 8 | 0.01072 | 1.0002 | 120.917 | 33.59 | 2386.4 | 33.60 | 2482.5 | 2516.1 | 0.1212 | 8.9501 | 8 |
| 10 | 0.01228 | 1.0004 | 106.379 | 42.00 | 2389.2 | 42.01 | 2477.7 | 2519.8 | 0.1510 | 8.9008 | 10 |
| 11 | 0.01312 | 1.0004 | 99.857 | 46.20 | 2390.5 | 46.20 | 2475.4 | 2521.6 | 0.1658 | 8.8765 | 11 |
| 12 | 0.01402 | 1.0005 | 93.784 | 50.41 | 2391.9 | 50.41 | 2473.0 | 2523.4 | 0.1806 | 8.8524 | 12 |
| 13 | 0.01497 | 1.0007 | 88.124 | 54.60 | 2393.3 | 54.60 | 2470.7 | 2525.3 | 0.1953 | 8.8285 | 13 |
| 14 | 0.01598 | 1.0008 | 82.848 | 58.79 | 2394.7 | 58.80 | 2468.3 | 2527.1 | 0.2099 | 8.8048 | 14 |
| 15 | 0.01705 | 1.0009 | 77.926 | 62.99 | 2396.1 | 62.99 | 2465.9 | 2528.9 | 0.2245 | 8.7814 | 15 |
| 16 | 0.01818 | 1.0011 | 73.333 | 67.18 | 2397.4 | 67.19 | 2463.6 | 2530.8 | 0.2390 | 8.7582 | 16 |
| 17 | 0.01938 | 1.0012 | 69.044 | 71.38 | 2398.8 | 71.38 | 2461.2 | 2532.6 | 0.2535 | 8.7351 | 17 |
| 18 | 0.02064 | 1.0014 | 65.038 | 75.57 | 2400.2 | 75.58 | 2458.8 | 2534.4 | 0.2679 | 8.7123 | 18 |
| 19 | 0.02198 | 1.0016 | 61.293 | 79.76 | 2401.6 | 79.77 | 2456.5 | 2536.2 | 0.2823 | 8.6897 | 19 |
| 20 | 0.02339 | 1.0018 | 57.791 | 83.95 | 2402.9 | 83.96 | 2454.1 | 2538.1 | 0.2966 | 8.6672 | 20 |
| 21 | 0.02487 | 1.0020 | 54.514 | 88.14 | 2404.3 | 88.14 | 2451.8 | 2539.9 | 0.3109 | 8.6450 | 21 |
| 22 | 0.02645 | 1.0022 | 51.447 | 92.32 | 2405.7 | 92.33 | 2449.4 | 2541.7 | 0.3251 | 8.6229 | 22 |
| 23 | 0.02810 | 1.0024 | 48.574 | 96.51 | 2407.0 | 96.52 | 2447.0 | 2543.5 | 0.3393 | 8.6011 | 23 |
| 24 | 0.02985 | 1.0027 | 45.883 | 100.70 | 2408.4 | 100.70 | 2444.7 | 2545.4 | 0.3534 | 8.5794 | 24 |
| 25 | 0.03169 | 1.0029 | 43.360 | 104.88 | 2409.8 | 104.89 | 2442.3 | 2547.2 | 0.3674 | 8.5580 | 25 |
| 26 | 0.03363 | 1.0032 | 40.994 | 109.06 | 2411.1 | 109.07 | 2439.9 | 2549.0 | 0.3814 | 8.5367 | 26 |
| 27 | 0.03567 | 1.0035 | 38.774 | 113.25 | 2412.5 | 113.25 | 2437.6 | 2550.8 | 0.3954 | 8.5156 | 27 |
| 28 | 0.03782 | 1.0037 | 36.690 | 117.42 | 2413.9 | 117.43 | 2435.2 | 2552.6 | 0.4093 | 8.4946 | 28 |
| 29 | 0.04008 | 1.0040 | 34.733 | 121.60 | 2415.2 | 121.61 | 2432.8 | 2554.5 | 0.4231 | 8.4739 | 29 |
| 30 | 0.04246 | 1.0043 | 32.894 | 125.78 | 2416.6 | 125.79 | 2430.5 | 2556.3 | 0.4369 | 8.4533 | 30 |
| 31 | 0.04496 | 1.0046 | 31.165 | 129.96 | 2418.0 | 129.97 | 2428.1 | 2558.1 | 0.4507 | 8.4329 | 31 |
| 32 | 0.04759 | 1.0050 | 29.540 | 134.14 | 2419.3 | 134.15 | 2425.7 | 2559.9 | 0.4644 | 8.4127 | 32 |
| 33 | 0.05034 | 1.0053 | 28.011 | 138.32 | 2420.7 | 138.33 | 2423.4 | 2561.7 | 0.4781 | 8.3927 | 33 |
| 34 | 0.05324 | 1.0056 | 26.571 | 142.50 | 2422.0 | 142.50 | 2421.0 | 2563.5 | 0.4917 | 8.3728 | 34 |
| 35 | 0.05628 | 1.0060 | 25.216 | 146.67 | 2423.4 | 146.68 | 2418.6 | 2565.3 | 0.5053 | 8.3531 | 35 |
| 36 | 0.05947 | 1.0063 | 23.940 | 150.85 | 2424.7 | 150.86 | 2416.2 | 2567.1 | 0.5188 | 8.3336 | 36 |
| 38 | 0.06632 | 1.0071 | 21.602 | 159.20 | 2427.4 | 159.21 | 2411.5 | 2570.7 | 0.5458 | 8.2950 | 38 |
| 40 | 0.07384 | 1.0078 | 19.523 | 167.56 | 2430.1 | 167.57 | 2406.7 | 2574.3 | 0.5725 | 8.2570 | 40 |
| 45 | 0.09593 | 1.0099 | 15.258 | 188.44 | 2436.8 | 188.45 | 2394.8 | 2583.2 | 0.6387 | 8.1648 | 45 |
| 50 | .1235 | 1.0121 | 12.032 | 209.32 | 2443.5 | 209.33 | 2382.7 | 2592.1 | .7038 | 8.0763 | 50 |
| 55 | .1576 | 1.0146 | 9.568 | 230.21 | 2450.1 | 230.23 | 2370.7 | 2600.9 | .7679 | 7.9913 | 55 |
| 60 | .1994 | 1.0172 | 7.671 | 251.11 | 2456.6 | 251.13 | 2358.5 | 2609.6 | .8312 | 7.9096 | 60 |
| 65 | .2503 | 1.0199 | 6.197 | 272.02 | 2463.1 | 272.06 | 2346.2 | 2618.3 | .8935 | 7.8310 | 65 |
| 70 | .3119 | 1.0228 | 5.042 | 292.95 | 2469.6 | 292.98 | 2333.8 | 2626.8 | .9549 | 7.7553 | 70 |
| 75 | .3858 | 1.0259 | 4.131 | 313.90 | 2475.9 | 313.93 | 2321.4 | 2635.3 | 1.0155 | 7.6824 | 75 |
| 80 | .4739 | 1.0291 | 3.407 | 334.86 | 2482.2 | 334.91 | 2308.8 | 2643.7 | 1.0753 | 7.6122 | 80 |
| 85 | .5783 | 1.0325 | 2.828 | 355.84 | 2488.4 | 355.90 | 2296.0 | 2651.9 | 1.1343 | 7.5445 | 85 |
| 90 | .7014 | 1.0360 | 2.361 | 376.85 | 2494.5 | 376.92 | 2283.2 | 2660.1 | 1.1925 | 7.4791 | 90 |
| 95 | .8455 | 1.0397 | 1.982 | 397.88 | 2500.6 | 397.96 | 2270.2 | 2668.1 | 1.2500 | 7.4159 | 95 |
| 100 | 1.014 | 1.0435 | 1.673 | 418.94 | 2506.5 | 419.04 | 2257.0 | 2676.1 | 1.3069 | 7.3549 | 100 |
| 110 | 1.433 | 1.0516 | 1.210 | 461.14 | 2518.1 | 461.30 | 2230.2 | 2691.5 | 1.4185 | 7.2387 | 110 |
| 120 | 1.985 | 1.0603 | 0.8919 | 503.50 | 2529.3 | 503.71 | 2202.6 | 2706.3 | 1.5276 | 7.1296 | 120 |
| 130 | 2.701 | 1.0697 | 0.6685 | 546.02 | 2539.9 | 546.31 | 2174.2 | 2720.5 | 1.6344 | 7.0269 | 130 |
| 140 | 3.613 | 1.0797 | 0.5089 | 588.74 | 2550.0 | 589.13 | 2144.7 | 2733.9 | 1.7391 | 6.9299 | 140 |
| 150 | 4.758 | 1.0905 | 0.3928 | 631.68 | 2559.5 | 632.20 | 2114.3 | 2746.5 | 1.8418 | 6.8379 | 150 |
| 160 | 6.178 | 1.1020 | 0.3071 | 674.86 | 2568.4 | 675.55 | 2082.6 | 2758.1 | 1.9427 | 6.7502 | 160 |
| 170 | 7.917 | 1.1143 | 0.2428 | 718.33 | 2576.5 | 719.21 | 2049.5 | 2768.7 | 2.0419 | 6.6663 | 170 |
| 180 | 10.02 | 1.1274 | 0.1941 | 762.09 | 2583.7 | 763.22 | 2015.0 | 2778.2 | 2.1396 | 6.5857 | 180 |
| 190 | 12.54 | 1.1414 | 0.1565 | 806.19 | 2590.0 | 807.62 | 1978.8 | 2786.4 | 2.2359 | 6.5079 | 190 |
| 200 | 15.54 | 1.1565 | 0.1274 | 850.65 | 2595.3 | 852.45 | 1940.7 | 2793.2 | 2.3309 | 6.4323 | 200 |
| 210 | 19.06 | 1.1726 | 0.1044 | 895.53 | 2599.5 | 897.76 | 1900.7 | 2798.5 | 2.4248 | 6.3585 | 210 |
| 220 | 23.18 | 1.1900 | 0.08619 | 940.87 | 2602.4 | 943.62 | 1858.5 | 2802.1 | 2.5178 | 6.2861 | 220 |
| 230 | 27.95 | 1.2088 | 0.07158 | 986.74 | 2603.9 | 990.12 | 1813.8 | 2804.0 | 2.6099 | 6.2146 | 230 |
| 240 | 33.44 | 1.2291 | 0.05976 | 1033.2 | 2604.0 | 1037.3 | 1766.5 | 2803.8 | 2.7015 | 6.1437 | 240 |
| 250 | 39.73 | 1.2512 | 0.05013 | 1080.4 | 2602.4 | 1085.4 | 1716.2 | 2801.5 | 2.7927 | 6.0730 | 250 |
| 260 | 46.88 | 1.2755 | 0.04221 | 1128.4 | 2599.0 | 1134.4 | 1662.5 | 2796.6 | 2.8838 | 6.0019 | 260 |
| 270 | 54.99 | 1.3023 | 0.03564 | 1177.4 | 2593.7 | 1184.5 | 1605.2 | 2789.7 | 2.9751 | 5.9301 | 270 |
| 280 | 64.12 | 1.3321 | 0.03017 | 1227.5 | 2586.1 | 1236.0 | 1543.6 | 2779.6 | 3.0668 | 5.8571 | 280 |
| 290 | 74.36 | 1.3656 | 0.02557 | 1278.9 | 2576.0 | 1289.1 | 1477.1 | 2766.2 | 3.1594 | 5.7821 | 290 |
| 300 | 85.81 | 1.4036 | 0.02167 | 1332.0 | 2563.0 | 1344.0 | 1404.9 | 2749.0 | 3.2534 | 5.7045 | 300 |
| 320 | 112.7 | 1.4988 | 0.01549 | 1444.6 | 2525.5 | 1461.5 | 1238.6 | 2700.1 | 3.4480 | 5.5362 | 320 |
| 340 | 145.9 | 1.6379 | 0.01080 | 1570.3 | 2464.6 | 1594.2 | 1027.9 | 2622.0 | 3.6594 | 5.3357 | 340 |
| 360 | 186.5 | 1.8925 | 0.006945 | 1725.2 | 2351.5 | 1760.5 | 720.5 | 2481.0 | 3.9147 | 5.0526 | 360 |
| 374.14 | 220.9 | 3.155 | 0.003155 | 2029.6 | 2029.6 | 2099.3 | 0 | 2099.3 | 4.4298 | 4.4298 | 374.14 |

Source: Tables A-2 through A-5 are extracted from J. H. Keenan, F. G. Keyes, P. G. Hill, and J. G. Moore, *Steam Tables*, Wiley, New York, 1969.

Properties of Saturated Water (Liquid-Vapor): Pressure Table

| Press. bar | Temp. °C | Specific Volume m³/kg | | Internal Energy kJ/kg | | Enthalpy kJ/kg | | Entropy kJ/kg · K | | Press. bar | | |
|------------------|-------------|-------------------------------------|------------------------|--------------------------|------------------------|-------------------------|---------------------------|------------------------|-------------------------|---------------|--------|-------|
| | | Sat. Liquid $v_f \times 10^3$ | Sat. Vapor v_g | Sat. Liquid u_f | Sat. Vapor u_g | Sat. Liquid h_f | Sat. Evap. h_{fg} | Sat. Vapor h_g | Sat. Liquid s_f | | | |
| H ₂ O | 0.04 | 28.96 | 1.0040 | 34.800 | 121.45 | 2415.2 | 121.46 | 2432.9 | 2554.4 | 0.4226 | 8.4746 | 0.04 |
| | 0.06 | 36.16 | 1.0064 | 23.739 | 151.53 | 2425.0 | 151.53 | 2415.9 | 2567.4 | 0.5210 | 8.3304 | 0.06 |
| | 0.08 | 41.51 | 1.0084 | 18.103 | 173.87 | 2432.2 | 173.88 | 2403.1 | 2577.0 | 0.5926 | 8.2287 | 0.08 |
| | 0.10 | 45.81 | 1.0102 | 14.674 | 191.82 | 2437.9 | 191.83 | 2392.8 | 2584.7 | 0.6493 | 8.1502 | 0.10 |
| | 0.20 | 60.06 | 1.0172 | 7.649 | 251.38 | 2456.7 | 251.40 | 2358.3 | 2609.7 | 0.8320 | 7.9085 | 0.20 |
| | 0.30 | 69.10 | 1.0223 | 5.229 | 289.20 | 2468.4 | 289.23 | 2336.1 | 2625.3 | 0.9439 | 7.7686 | 0.30 |
| | 0.40 | 75.87 | 1.0265 | 3.993 | 317.53 | 2477.0 | 317.58 | 2319.2 | 2636.8 | 1.0259 | 7.6700 | 0.40 |
| | 0.50 | 81.33 | 1.0300 | 3.240 | 340.44 | 2483.9 | 340.49 | 2305.4 | 2645.9 | 1.0910 | 7.5939 | 0.50 |
| | 0.60 | 85.94 | 1.0331 | 2.732 | 359.79 | 2489.6 | 359.86 | 2293.6 | 2653.5 | 1.1453 | 7.5320 | 0.60 |
| | 0.70 | 89.95 | 1.0360 | 2.365 | 376.63 | 2494.5 | 376.70 | 2283.3 | 2660.0 | 1.1919 | 7.4797 | 0.70 |
| | 0.80 | 93.50 | 1.0380 | 2.087 | 391.58 | 2498.8 | 391.66 | 2274.1 | 2665.8 | 1.2329 | 7.4346 | 0.80 |
| | 0.90 | 96.71 | 1.0410 | 1.869 | 405.06 | 2502.6 | 405.15 | 2265.7 | 2670.9 | 1.2695 | 7.3949 | 0.90 |
| | 1.00 | 99.63 | 1.0432 | 1.694 | 417.36 | 2506.1 | 417.46 | 2258.0 | 2675.5 | 1.3026 | 7.3594 | 1.00 |
| | 1.50 | 111.4 | 1.0528 | 1.159 | 466.94 | 2519.7 | 467.11 | 2226.5 | 2693.6 | 1.4336 | 7.2233 | 1.50 |
| | 2.00 | 120.2 | 1.0605 | 0.8857 | 504.49 | 2529.5 | 504.70 | 2201.9 | 2706.7 | 1.5301 | 7.1271 | 2.00 |
| | 2.50 | 127.4 | 1.0672 | 0.7187 | 535.10 | 2537.2 | 535.37 | 2181.5 | 2716.9 | 1.6072 | 7.0527 | 2.50 |
| | 3.00 | 133.6 | 1.0732 | 0.6058 | 561.15 | 2543.6 | 561.47 | 2163.8 | 2725.3 | 1.6718 | 6.9919 | 3.00 |
| | 3.50 | 138.9 | 1.0786 | 0.5243 | 583.95 | 2546.9 | 584.33 | 2148.1 | 2732.4 | 1.7275 | 6.9405 | 3.50 |
| | 4.00 | 143.6 | 1.0836 | 0.4625 | 604.31 | 2553.6 | 604.74 | 2133.8 | 2738.6 | 1.7766 | 6.8959 | 4.00 |
| | 4.50 | 147.9 | 1.0882 | 0.4140 | 622.25 | 2557.6 | 623.25 | 2120.7 | 2743.9 | 1.8207 | 6.8565 | 4.50 |
| | 5.00 | 151.9 | 1.0926 | 0.3749 | 639.68 | 2561.2 | 640.23 | 2108.5 | 2748.7 | 1.8607 | 6.8212 | 5.00 |
| | 6.00 | 158.9 | 1.1006 | 0.3157 | 669.90 | 2567.4 | 670.56 | 2086.3 | 2756.8 | 1.9312 | 6.7600 | 6.00 |
| | 7.00 | 165.0 | 1.1080 | 0.2729 | 696.44 | 2572.5 | 697.22 | 2066.3 | 2763.5 | 1.9922 | 6.7080 | 7.00 |
| | 8.00 | 170.4 | 1.1148 | 0.2404 | 720.22 | 2576.8 | 721.11 | 2048.0 | 2769.1 | 2.0462 | 6.6628 | 8.00 |
| | 9.00 | 175.4 | 1.1212 | 0.2150 | 741.83 | 2580.5 | 742.83 | 2031.1 | 2773.9 | 2.0946 | 6.6226 | 9.00 |
| | 10.0 | 179.9 | 1.1273 | 0.1944 | 761.68 | 2583.6 | 762.81 | 2015.3 | 2778.1 | 2.1387 | 6.5863 | 10.0 |
| | 15.0 | 198.3 | 1.1539 | 0.1318 | 843.16 | 2594.5 | 844.84 | 1947.3 | 2792.2 | 2.3150 | 6.4448 | 15.0 |
| | 20.0 | 212.4 | 1.1767 | 0.09963 | 906.44 | 2600.3 | 908.79 | 1890.7 | 2799.5 | 2.4474 | 6.3409 | 20.0 |
| | 25.0 | 224.0 | 1.1973 | 0.07998 | 959.11 | 2603.1 | 962.11 | 1841.0 | 2803.1 | 2.5547 | 6.2575 | 25.0 |
| | 30.0 | 233.9 | 1.2165 | 0.06668 | 1004.8 | 2604.1 | 1008.4 | 1795.7 | 2804.2 | 2.6457 | 6.1869 | 30.0 |
| | 35.0 | 242.6 | 1.2347 | 0.05707 | 1045.4 | 2603.7 | 1049.8 | 1753.7 | 2803.4 | 2.7253 | 6.1253 | 35.0 |
| | 40.0 | 250.4 | 1.2522 | -0.04978 | 1082.3 | 2602.3 | 1087.3 | 1714.1 | 2801.4 | 2.7964 | 6.0701 | 40.0 |
| | 45.0 | 257.5 | 1.2692 | 0.04406 | 1116.2 | 2600.1 | 1121.9 | 1676.4 | 2798.3 | 2.8610 | 6.0199 | 45.0 |
| | 50.0 | 264.0 | 1.2859 | 0.03944 | 1147.8 | 2597.1 | 1154.2 | 1640.1 | 2794.3 | 2.9202 | 5.9734 | 50.0 |
| | 60.0 | 275.6 | 1.3187 | 0.03244 | 1205.4 | 2589.7 | 1213.4 | 1571.0 | 2784.3 | 3.0267 | 5.8892 | 60.0 |
| | 70.0 | 285.9 | 1.3513 | 0.02737 | 1257.6 | 2580.5 | 1267.0 | 1505.1 | 2772.1 | 3.1211 | 5.8133 | 70.0 |
| | 80.0 | 295.1 | 1.3842 | 0.02352 | 1305.6 | 2569.8 | 1316.6 | 1441.3 | 2758.0 | 3.2068 | 5.7432 | 80.0 |
| | 90.0 | 303.4 | 1.4178 | 0.02048 | 1350.5 | 2557.8 | 1363.3 | 1378.9 | 2742.1 | 3.2858 | 5.6772 | 90.0 |
| | 100. | 311.1 | 1.4524 | 0.01803 | 1393.0 | 2544.4 | 1407.6 | 1317.1 | 2724.7 | 3.3596 | 5.6141 | 100. |
| | 110. | 318.2 | 1.4886 | 0.01599 | 1433.7 | 2529.8 | 1450.1 | 1255.5 | 2705.6 | 3.4295 | 5.5527 | 110. |
| | 120. | 324.8 | 1.5267 | 0.01426 | 1473.0 | 2513.7 | 1491.3 | 1193.6 | 2684.9 | 3.4962 | 5.4924 | 120. |
| | 130. | 330.9 | 1.5671 | 0.01278 | 1511.1 | 2496.1 | 1531.5 | 1130.7 | 2662.2 | 3.5606 | 5.4323 | 130. |
| | 140. | 336.8 | 1.6107 | 0.01149 | 1548.6 | 2476.8 | 1571.1 | 1066.5 | 2637.6 | 3.6232 | 5.3717 | 140. |
| | 150. | 342.2 | 1.6581 | 0.01034 | 1585.6 | 2455.5 | 1610.5 | 1000.0 | 2610.5 | 3.6848 | 5.3098 | 150. |
| | 160. | 347.4 | 1.7107 | 0.009306 | 1622.7 | 2431.7 | 1650.1 | 930.6 | 2580.6 | 3.7461 | 5.2455 | 160. |
| | 170. | 352.4 | 1.7702 | 0.008364 | 1660.2 | 2405.0 | 1690.3 | 856.9 | 2547.2 | 3.8079 | 5.1777 | 170. |
| | 180. | 357.1 | 1.8397 | 0.007489 | 1698.9 | 2374.3 | 1732.0 | 777.1 | 2509.1 | 3.8715 | 5.1044 | 180. |
| | 190. | 361.5 | 1.9243 | 0.006657 | 1739.9 | 2338.1 | 1776.5 | 688.0 | 2464.5 | 3.9388 | 5.0228 | 190. |
| | 200. | 365.8 | 2.036 | 0.005834 | 1785.6 | 2293.0 | 1826.3 | 583.4 | 2409.7 | 4.0139 | 4.9269 | 200. |
| | 220.9 | 374.1 | 3.155 | 0.003155 | 2029.6 | 2029.6 | 2099.3 | 0 | 2099.3 | 4.4298 | 4.4298 | 220.9 |

H₂O

H₂O

TABLE A-4 Properties of Superheated Water Vapor

| T °C | v m ³ /kg | u kJ/kg | h kJ/kg | s kJ/kg · K | v m ³ /kg | u kJ/kg | h kJ/kg | s kJ/kg · K |
|--|-------------------------|------------|------------|----------------|-------------------------|------------|------------|----------------|
| $p = 0.06 \text{ bar} = 0.006 \text{ MPa}$ ($T_{\text{sat}} = 36.16^\circ\text{C}$) | | | | | | | | |
| $p = 0.35 \text{ bar} = 0.035 \text{ MPa}$ ($T_{\text{sat}} = 72.69^\circ\text{C}$) | | | | | | | | |
| Sat. | 23.739 | 2425.0 | 2567.4 | 8.3304 | 4.526 | 2473.0 | 2631.4 | 7.7158 |
| 80 | 27.132 | 2487.3 | 2650.1 | 8.5804 | 4.625 | 2483.7 | 2645.6 | 7.7564 |
| 120 | 30.219 | 2544.7 | 2726.0 | 8.7840 | 5.163 | 2542.4 | 2723.1 | 7.9644 |
| 160 | 33.302 | 2602.7 | 2802.5 | 8.9693 | 5.696 | 2601.2 | 2800.6 | 8.1519 |
| 200 | 36.383 | 2661.4 | 2879.7 | 9.1398 | 6.228 | 2660.4 | 2878.4 | 8.3237 |
| 240 | 39.462 | 2721.0 | 2957.8 | 9.2982 | 6.758 | 2720.3 | 2956.8 | 8.4828 |
| 280 | 42.540 | 2781.5 | 3036.8 | 9.4464 | 7.287 | 2780.9 | 3036.0 | 8.6314 |
| 320 | 45.618 | 2843.0 | 3116.7 | 9.5859 | 7.815 | 2842.5 | 3116.1 | 8.7712 |
| 360 | 48.696 | 2905.5 | 3197.7 | 9.7180 | 8.344 | 2905.1 | 3197.1 | 8.9034 |
| 400 | 51.774 | 2969.0 | 3279.6 | 9.8435 | 8.872 | 2968.6 | 3279.2 | 9.0291 |
| 440 | 54.851 | 3033.5 | 3362.6 | 9.9633 | 9.400 | 3033.2 | 3362.2 | 9.1490 |
| 500 | 59.467 | 3132.3 | 3489.1 | 10.1336 | 10.192 | 3132.1 | 3488.8 | 9.3194 |
| $p = 0.70 \text{ bar} = 0.07 \text{ MPa}$ ($T_{\text{sat}} = 89.95^\circ\text{C}$) | | | | | | | | |
| $p = 1.0 \text{ bar} = 0.10 \text{ MPa}$ ($T_{\text{sat}} = 99.63^\circ\text{C}$) | | | | | | | | |
| Sat. | 2.365 | 2494.5 | 2660.0 | 7.4797 | 1.694 | 2506.1 | 2675.5 | 7.3594 |
| 100 | 2.434 | 2509.7 | 2680.0 | 7.5341 | 1.696 | 2506.7 | 2676.2 | 7.3614 |
| 120 | 2.571 | 2539.7 | 2719.6 | 7.6375 | 1.793 | 2537.3 | 2716.6 | 7.4668 |
| 160 | 2.841 | 2599.4 | 2798.2 | 7.8279 | 1.984 | 2597.8 | 2796.2 | 7.6597 |
| 200 | 3.108 | 2659.1 | 2876.7 | 8.0012 | 2.172 | 2658.1 | 2875.3 | 7.8343 |
| 240 | 3.374 | 2719.3 | 2955.5 | 8.1611 | 2.359 | 2718.5 | 2954.5 | 7.9949 |
| 280 | 3.640 | 2780.2 | 3035.0 | 8.3162 | 2.546 | 2779.6 | 3034.2 | 8.1445 |
| 320 | 3.905 | 2842.0 | 3115.3 | 8.4504 | 2.732 | 2841.5 | 3114.6 | 8.2849 |
| 360 | 4.170 | 2904.6 | 3196.5 | 8.5828 | 2.917 | 2904.2 | 3195.9 | 8.4175 |
| 400 | 4.434 | 2968.2 | 3278.6 | 8.7086 | 3.103 | 2967.9 | 3278.2 | 8.5435 |
| 440 | 4.698 | 3032.9 | 3361.8 | 8.8286 | 3.288 | 3032.6 | 3361.4 | 8.6636 |
| 500 | 5.095 | 3131.8 | 3488.5 | 8.9991 | 3.565 | 3131.6 | 3488.1 | 8.8342 |
| $p = 1.5 \text{ bar} = 0.15 \text{ MPa}$ ($T_{\text{sat}} = 111.37^\circ\text{C}$) | | | | | | | | |
| $p = 3.0 \text{ bar} = 0.30 \text{ MPa}$ ($T_{\text{sat}} = 133.55^\circ\text{C}$) | | | | | | | | |
| Sat. | 1.159 | 2519.7 | 2693.6 | 7.2233 | 0.606 | 2543.6 | 2725.3 | 6.9919 |
| 120 | 1.188 | 2533.3 | 2711.4 | 7.2693 | 0.651 | 2587.1 | 2782.3 | 7.1276 |
| 160 | 1.317 | 2595.2 | 2792.8 | 7.4665 | 0.716 | 2650.7 | 2865.5 | 7.3115 |
| 200 | 1.444 | 2656.2 | 2872.9 | 7.6433 | 0.781 | 2713.1 | 2947.3 | 7.4774 |
| 240 | 1.570 | 2717.2 | 2952.7 | 7.8052 | 0.844 | 2775.4 | 3028.6 | 7.6299 |
| 280 | 1.695 | 2778.6 | 3032.8 | 7.9555 | 0.907 | 2838.1 | 3110.1 | 7.7722 |
| 320 | 1.819 | 2840.6 | 3113.5 | 8.0964 | 0.969 | 2901.4 | 3192.2 | 7.9061 |
| 360 | 1.943 | 2903.5 | 3195.0 | 8.2293 | 1.032 | 2965.6 | 3275.0 | 8.0330 |
| 400 | 2.067 | 2967.3 | 3277.4 | 8.3555 | 1.094 | 3030.6 | 3358.7 | 8.1538 |
| 440 | 2.191 | 3032.1 | 3360.7 | 8.4757 | 1.187 | 3130.0 | 3486.0 | 8.3251 |
| 500 | 2.376 | 3131.2 | 3487.6 | 8.6466 | 1.341 | 3300.8 | 3703.2 | 8.5892 |
| $p = 5.0 \text{ bar} = 0.50 \text{ MPa}$ ($T_{\text{sat}} = 151.86^\circ\text{C}$) | | | | | | | | |
| $p = 7.0 \text{ bar} = 0.70 \text{ MPa}$ ($T_{\text{sat}} = 164.97^\circ\text{C}$) | | | | | | | | |
| Sat. | 0.3749 | 2561.2 | 2748.7 | 6.8213 | 0.2729 | 2572.5 | 2763.5 | 6.7080 |
| 180 | 0.4045 | 2609.7 | 2812.0 | 6.9656 | 0.2847 | 2599.8 | 2799.1 | 6.7880 |
| 200 | 0.4249 | 2642.9 | 2855.4 | 7.0592 | 0.2999 | 2634.8 | 2844.8 | 6.8865 |
| 240 | 0.4646 | 2707.6 | 2939.9 | 7.2307 | 0.3292 | 2701.8 | 2932.2 | 7.0641 |
| 280 | 0.5034 | 2771.2 | 3022.9 | 7.3865 | 0.3574 | 2766.9 | 3017.1 | 7.2233 |
| 320 | 0.5416 | 2834.7 | 3105.6 | 7.5308 | 0.3852 | 2831.3 | 3100.9 | 7.3697 |
| 360 | 0.5796 | 2898.7 | 3188.4 | 7.6660 | 0.4126 | 2895.8 | 3184.7 | 7.5063 |
| 400 | 0.6173 | 2963.2 | 3271.9 | 7.7938 | 0.4397 | 2960.9 | 3268.7 | 7.6350 |
| 440 | 0.6548 | 3028.6 | 3356.0 | 7.9152 | 0.4667 | 3026.6 | 3353.3 | 7.7571 |
| 500 | 0.7109 | 3128.4 | 3483.9 | 8.0873 | 0.5070 | 3126.8 | 3481.7 | 7.9299 |
| 600 | 0.8041 | 3299.6 | 3701.7 | 8.3522 | 0.5738 | 3298.5 | 3700.2 | 8.1956 |
| 700 | 0.8969 | 3477.5 | 3925.9 | 8.5952 | 0.6403 | 3476.6 | 3924.8 | 8.4391 |
| $p = 10.0 \text{ bar} = 1.0 \text{ MPa}$ ($T_{\text{sat}} = 179.91^\circ\text{C}$) | | | | | | | | |
| $p = 15.0 \text{ bar} = 1.5 \text{ MPa}$ ($T_{\text{sat}} = 198.32^\circ\text{C}$) | | | | | | | | |
| Sat. | 0.1944 | 2583.6 | 2778.1 | 6.5865 | 0.1318 | 2594.5 | 2792.2 | 6.4448 |
| 200 | 0.2060 | 2621.9 | 2827.9 | 6.6940 | 0.1325 | 2598.1 | 2796.8 | 6.4546 |
| 240 | 0.2275 | 2692.9 | 2920.4 | 6.8817 | 0.1483 | 2676.9 | 2899.3 | 6.6628 |
| 280 | 0.2480 | 2760.2 | 3008.2 | 7.0465 | 0.1627 | 2748.6 | 2992.7 | 6.8381 |
| 320 | 0.2678 | 2826.1 | 3093.9 | 7.1962 | 0.1765 | 2817.1 | 3081.9 | 6.9938 |
| 360 | 0.2873 | 2891.6 | 3178.9 | 7.3349 | 0.1899 | 2884.4 | 3169.2 | 7.1363 |
| 400 | 0.3066 | 2957.3 | 3263.9 | 7.4651 | 0.2030 | 2951.3 | 3255.8 | 7.2690 |
| 440 | 0.3257 | 3023.6 | 3349.3 | 7.5883 | 0.2160 | 3018.5 | 3342.5 | 7.3940 |
| 500 | 0.3541 | 3124.4 | 3478.5 | 7.7622 | 0.2352 | 3120.3 | 3473.1 | 7.5698 |
| 540 | 0.3729 | 3192.6 | 3565.6 | 7.8720 | 0.2478 | 3189.1 | 3560.9 | 7.6805 |
| 600 | 0.4011 | 3296.8 | 3697.9 | 8.0290 | 0.2668 | 3293.9 | 3694.0 | 7.8385 |
| 640 | 0.4198 | 3367.4 | 3787.2 | 8.1290 | 0.2793 | 3364.8 | 3783.8 | 7.9391 |

H₂O

TABLE A-4 (Continued)

| T °C | v m³/kg | u kJ/kg | h kJ/kg | s kJ/kg · K | v m³/kg | u kJ/kg | h kJ/kg | s kJ/kg · K | |
|---|------------|------------|------------|----------------|---|------------|------------|----------------|--|
| $p = 20.0 \text{ bar} = 2.0 \text{ MPa}$ ($T_{\text{sat}} = 212.42^\circ\text{C}$) | | | | | $p = 30.0 \text{ bar} = 3.0 \text{ MPa}$ ($T_{\text{sat}} = 233.90^\circ\text{C}$) | | | | |
| Sat. | 0.0996 | 2600.3 | 2799.5 | 6.3409 | 0.0667 | 2604.1 | 2804.2 | 6.1869 | |
| 240 | 0.1085 | 2659.6 | 2876.5 | 6.4952 | 0.0682 | 2619.7 | 2824.3 | 6.2265 | |
| 280 | 0.1200 | 2736.4 | 2976.4 | 6.6828 | 0.0771 | 2709.9 | 2941.3 | 6.4462 | |
| 320 | 0.1308 | 2807.9 | 3069.5 | 6.8452 | 0.0850 | 2788.4 | 3043.4 | 6.6245 | |
| 360 | 0.1411 | 2877.0 | 3159.3 | 6.9917 | 0.0923 | 2861.7 | 3138.7 | 6.7801 | |
| 400 | 0.1512 | 2945.2 | 3247.6 | 7.1271 | 0.0994 | 2932.8 | 3230.9 | 6.9212 | |
| 440 | 0.1611 | 3013.4 | 3335.5 | 7.2540 | 0.1062 | 3002.9 | 3321.5 | 7.0520 | |
| 500 | 0.1757 | 3116.2 | 3467.6 | 7.4317 | 0.1162 | 3108.0 | 3456.5 | 7.2338 | |
| 540 | 0.1853 | 3185.6 | 3556.1 | 7.5434 | 0.1227 | 3178.4 | 3546.6 | 7.3474 | |
| 600 | 0.1996 | 3290.9 | 3690.1 | 7.7024 | 0.1324 | 3285.0 | 3682.3 | 7.5085 | |
| 640 | 0.2091 | 3362.2 | 3780.4 | 7.8035 | 0.1388 | 3357.0 | 3773.5 | 7.6106 | |
| 700 | 0.2232 | 3470.9 | 3917.4 | 7.9487 | 0.1484 | 3466.5 | 3911.7 | 7.7571 | |
| $p = 40 \text{ bar} = 4.0 \text{ MPa}$ ($T_{\text{sat}} = 250.4^\circ\text{C}$) | | | | | $p = 60 \text{ bar} = 6.0 \text{ MPa}$ ($T_{\text{sat}} = 275.64^\circ\text{C}$) | | | | |
| Sat. | 0.04978 | 2602.3 | 2801.4 | 6.0701 | 0.03244 | 2589.7 | 2784.3 | 5.8892 | |
| 280 | 0.05546 | 2680.0 | 2901.8 | 6.2568 | 0.03317 | 2605.2 | 2804.2 | 5.9252 | |
| 320 | 0.06199 | 2767.4 | 3015.4 | 6.4553 | 0.03876 | 2720.0 | 2952.6 | 6.1846 | |
| 360 | 0.06788 | 2845.7 | 3117.2 | 6.6215 | 0.04331 | 2811.2 | 3071.1 | 6.3782 | |
| 400 | 0.07341 | 2919.9 | 3213.6 | 6.7690 | 0.04739 | 2892.9 | 3177.2 | 6.5408 | |
| 440 | 0.07872 | 2992.2 | 3307.1 | 6.9041 | 0.05122 | 2970.0 | 3277.3 | 6.6853 | |
| 500 | 0.08643 | 3099.5 | 3445.3 | 7.0901 | 0.05665 | 3082.2 | 3422.2 | 6.8803 | |
| 540 | 0.09145 | 3171.1 | 3536.9 | 7.2056 | 0.06015 | 3156.1 | 3517.0 | 6.9999 | |
| 600 | 0.09885 | 3279.1 | 3674.4 | 7.3688 | 0.06525 | 3266.9 | 3658.4 | 7.1677 | |
| 640 | 0.1037 | 3351.8 | 3766.6 | 7.4720 | 0.06859 | 3341.0 | 3752.6 | 7.2731 | |
| 700 | 0.1110 | 3462.1 | 3905.9 | 7.6198 | 0.07352 | 3453.1 | 3894.1 | 7.4234 | |
| 740 | 0.1157 | 3536.6 | 3999.6 | 7.7141 | 0.07677 | 3528.3 | 3989.2 | 7.5190 | |
| $p = 80 \text{ bar} = 8.0 \text{ MPa}$ ($T_{\text{sat}} = 295.06^\circ\text{C}$) | | | | | $p = 100 \text{ bar} = 10.0 \text{ MPa}$ ($T_{\text{sat}} = 311.06^\circ\text{C}$) | | | | |
| Sat. | 0.02352 | 2569.8 | 2758.0 | 5.7432 | 0.01803 | 2544.4 | 2724.7 | 5.6141 | |
| 320 | 0.02682 | 2662.7 | 2877.2 | 5.9489 | 0.01925 | 2588.8 | 2781.3 | 5.7103 | |
| 360 | 0.03089 | 2772.7 | 3019.8 | 6.1819 | 0.02331 | 2729.1 | 2962.1 | 6.0060 | |
| 400 | 0.03432 | 2863.8 | 3138.3 | 6.3634 | 0.02641 | 2832.4 | 3096.5 | 6.2120 | |
| 440 | 0.03742 | 2946.7 | 3246.1 | 6.5190 | 0.02911 | 2922.1 | 3213.2 | 6.3805 | |
| 480 | 0.04034 | 3025.7 | 3348.4 | 6.6586 | 0.03160 | 3005.4 | 3321.4 | 6.5282 | |
| 520 | 0.04313 | 3102.7 | 3447.7 | 6.7871 | 0.03394 | 3085.6 | 3425.1 | 6.6622 | |
| 560 | 0.04582 | 3178.7 | 3545.3 | 6.9072 | 0.03619 | 3164.1 | 3526.0 | 6.7864 | |
| 600 | 0.04845 | 3254.4 | 3642.0 | 7.0206 | 0.03837 | 3241.7 | 3625.3 | 6.9029 | |
| 640 | 0.05102 | 3330.1 | 3738.3 | 7.1283 | 0.04048 | 3318.9 | 3723.7 | 7.0131 | |
| 700 | 0.05481 | 3443.9 | 3882.4 | 7.2812 | 0.04358 | 3434.7 | 3870.5 | 7.1687 | |
| 740 | 0.05729 | 3520.4 | 3978.7 | 7.3782 | 0.04560 | 3512.1 | 3968.1 | 7.2670 | |
| $p = 120 \text{ bar} = 12.0 \text{ MPa}$ ($T_{\text{sat}} = 324.75^\circ\text{C}$) | | | | | $p = 140 \text{ bar} = 14.0 \text{ MPa}$ ($T_{\text{sat}} = 336.75^\circ\text{C}$) | | | | |
| Sat. | 0.01426 | 2513.7 | 2684.9 | 5.4924 | 0.01149 | 2476.8 | 2637.6 | 5.3717 | |
| 360 | 0.01811 | 2678.4 | 2895.7 | 5.8361 | 0.01422 | 2617.4 | 2816.5 | 5.6602 | |
| 400 | 0.02108 | 2798.3 | 3051.3 | 6.0747 | 0.01722 | 2760.9 | 3001.9 | 5.9448 | |
| 440 | 0.02355 | 2896.1 | 3178.7 | 6.2586 | 0.01954 | 2868.6 | 3142.2 | 6.1474 | |
| 480 | 0.02576 | 2984.4 | 3293.5 | 6.4154 | 0.02157 | 2962.5 | 3264.5 | 6.3143 | |
| 520 | 0.02781 | 3068.0 | 3401.8 | 6.5555 | 0.02343 | 3049.8 | 3377.8 | 6.4610 | |
| 560 | 0.02977 | 3149.0 | 3506.2 | 6.6840 | 0.02517 | 3133.6 | 3486.0 | 6.5941 | |
| 600 | 0.03164 | 3228.7 | 3608.3 | 6.8037 | 0.02683 | 3215.4 | 3591.1 | 6.7172 | |
| 640 | 0.03345 | 3307.5 | 3709.0 | 6.9164 | 0.02843 | 3296.0 | 3694.1 | 6.8326 | |
| 700 | 0.03610 | 3425.2 | 3858.4 | 7.0749 | 0.03075 | 3415.7 | 3846.2 | 6.9939 | |
| 740 | 0.03781 | 3503.7 | 3957.4 | 7.1746 | 0.03225 | 3495.2 | 3946.7 | 7.0952 | |

 H_2O

TABLE A-4 (Continued)

| T °C | v m ³ /kg | u kJ/kg | h kJ/kg | s kJ/kg · K | v m ³ /kg | u kJ/kg | h kJ/kg | s kJ/kg · K |
|--|-------------------------|------------|------------|----------------|-------------------------|------------|------------|----------------|
| <i>p</i> = 160 bar = 16.0 MPa (T _{sat} = 347.44°C) | | | | | | | | |
| <i>p</i> = 180 bar = 18.0 MPa (T _{sat} = 357.06°C) | | | | | | | | |
| Sat. | 0.00931 | 2431.7 | 2580.6 | 5.2455 | 0.00749 | 2374.3 | 2509.1 | 5.1044 |
| 360 | 0.01105 | 2539.0 | 2715.8 | 5.4614 | 0.00809 | 2418.9 | 2564.5 | 5.1922 |
| 400 | 0.01426 | 2719.4 | 2947.6 | 5.8175 | 0.01190 | 2672.8 | 2887.0 | 5.6887 |
| 440 | 0.01652 | 2839.4 | 3103.7 | 6.0429 | 0.01414 | 2808.2 | 3062.8 | 5.9428 |
| 480 | 0.01842 | 2939.7 | 3234.4 | 6.2215 | 0.01596 | 2915.9 | 3203.2 | 6.1345 |
| 520 | 0.02013 | 3031.1 | 3353.3 | 6.3752 | 0.01757 | 3011.8 | 3378.0 | 6.2960 |
| 560 | 0.02172 | 3117.8 | 3465.4 | 6.5132 | 0.01904 | 3101.7 | 3444.4 | 6.4392 |
| 600 | 0.02323 | 3201.8 | 3573.5 | 6.6399 | 0.02042 | 3188.0 | 3555.6 | 6.5696 |
| 640 | 0.02467 | 3284.2 | 3678.9 | 6.7580 | 0.02174 | 3272.3 | 3663.6 | 6.6905 |
| 700 | 0.02674 | 3406.0 | 3833.9 | 6.9224 | 0.02362 | 3396.3 | 3821.5 | 6.8580 |
| 740 | 0.02808 | 3486.7 | 3935.9 | 7.0251 | 0.02483 | 3478.0 | 3925.0 | 6.9623 |

 H_2O

| <i>p</i> = 200 bar = 20.0 MPa (T _{sat} = 365.81°C) | | | | <i>p</i> = 240 bar = 24.0 MPa | | | |
|--|---------|--------|--------|-------------------------------|---------|--------|--------|
| Sat. | 0.00583 | 2293.0 | 2409.7 | 4.9269 | | | |
| 400 | 0.00994 | 2619.3 | 2818.1 | 5.5540 | 0.00673 | 2477.8 | 2639.4 |
| 440 | 0.01222 | 2774.9 | 3019.4 | 5.8450 | 0.00929 | 2700.6 | 2923.4 |
| 480 | 0.01399 | 2891.2 | 3170.8 | 6.0518 | 0.01100 | 2838.3 | 3102.3 |
| 520 | 0.01551 | 2992.0 | 3302.2 | 6.2218 | 0.01241 | 2950.5 | 3248.5 |
| 560 | 0.01689 | 3085.2 | 3423.0 | 6.3705 | 0.01366 | 3051.1 | 3379.0 |
| 600 | 0.01818 | 3174.0 | 3537.6 | 6.5048 | 0.01481 | 3145.2 | 3500.7 |
| 640 | 0.01940 | 3260.2 | 3648.1 | 6.6286 | 0.01588 | 3235.5 | 3616.7 |
| 700 | 0.02113 | 3386.4 | 3809.0 | 6.7993 | 0.01739 | 3366.4 | 3783.8 |
| 740 | 0.02224 | 3469.3 | 3914.1 | 6.9052 | 0.01835 | 3451.7 | 3892.1 |
| 800 | 0.02385 | 3592.7 | 4069.7 | 7.0544 | 0.01974 | 3578.0 | 4051.6 |

| <i>p</i> = 280 bar = 28.0 MPa | | | | <i>p</i> = 320 bar = 32.0 MPa | | | |
|-------------------------------|---------|--------|--------|-------------------------------|---------|--------|--------|
| 400 | 0.00383 | 2223.5 | 2330.7 | 4.7494 | 0.00236 | 1980.4 | 2055.9 |
| 440 | 0.00712 | 2613.2 | 2812.6 | 5.4494 | 0.00544 | 2509.0 | 2683.0 |
| 480 | 0.00885 | 2780.8 | 3028.5 | 5.7446 | 0.00722 | 2718.1 | 2949.2 |
| 520 | 0.01020 | 2906.8 | 3192.3 | 5.9566 | 0.00853 | 2860.7 | 3133.7 |
| 560 | 0.01136 | 3015.7 | 3333.7 | 6.1307 | 0.00963 | 2979.0 | 3287.2 |
| 600 | 0.01241 | 3115.6 | 3463.0 | 6.2823 | 0.01061 | 3085.3 | 3424.6 |
| 640 | 0.01338 | 3210.3 | 3584.8 | 6.4187 | 0.01150 | 3184.5 | 3552.5 |
| 700 | 0.01473 | 3346.1 | 3758.4 | 6.6029 | 0.01273 | 3325.4 | 3732.8 |
| 740 | 0.01558 | 3433.9 | 3870.0 | 6.7153 | 0.01350 | 3415.9 | 3847.8 |
| 800 | 0.01680 | 3563.1 | 4033.4 | 6.8720 | 0.01460 | 3548.0 | 4015.1 |
| 900 | 0.01873 | 3774.3 | 4298.8 | 7.1084 | 0.01633 | 3762.7 | 4285.1 |