L-2/T-2/EEE **Date : 26/12/2012**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-e/T-2 B. Sc. Engineering Examinations 2010-2011

Sub : **EEE 209** (Engineering Electromagnetics)

Full Marks: 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

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

The questions are of equal value.

1. (a) Show that

$$\oint \overline{D} \cdot \overline{dS} = \int_V \rho \, dV$$

$$\nabla \cdot \overline{D} = \rho$$

$$\overline{E} = -\nabla \phi$$

$$\nabla^2 \phi = -\rho/\varepsilon$$

The symbols have their usual meaning.

(b) Show that the capacitance per unit length of a parallel wire transmission line is expressed as $C = \dfrac{\pi\varepsilon}{\cos h^{-1}(D/2a)}$ F/m

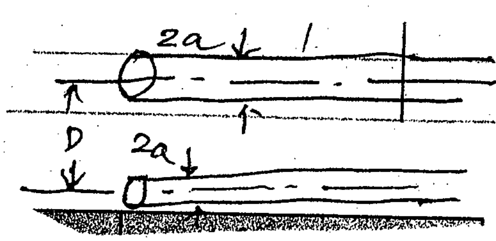


Fig. for Q.1(b)

2. (a) For an electrostatic dipole having moment $\overline{P} = q\overline{d}$, show that the potential at distance R is

$$\phi = \frac{\overline{P} \cdot \hat{a}_R}{4\pi\varepsilon_0 R^2}$$

$\hat{a}_R$ is unit vector in the direction of R. $\varepsilon_0$ is the permittivity of the medium. From the above expression of $\phi$ show that electrostatic field is expressed as

$$\overline{E} = \frac{P}{4\pi\varepsilon_0 R^3}(\hat{a}_R 2\cos\theta + \hat{a}_\theta \sin\theta)$$

$\hat{a}_\theta$ is unit vector in $\theta$-direction.

(b) Show that the energy required to assemble a charge density $\rho$ $c/m^3$ in a sphere of radius 'b' is

$$U_E = \frac{4\pi\rho^2}{15\varepsilon_0} b^5$$

Contd .......... P/2

**EEE 209**

3. (a) State and explain Biot-Savart's law. Prove that

$$\overline{B} = \nabla \times \overline{A},\ \nabla \cdot \overline{B} = 0, \nabla^2 \overline{A} = -\mu \overline{J}$$

The symbols have their usual meaning.

(b) Show that for a solenoid having n turns per unit length and carrying current I in air

$$\overline{B} = \hat{z}\,\mu_0\, n H \quad I$$

4. (a) Show that Lorentz's force associated with a moving charge q is expressed as

$$\overline{F}_0 = q\left(\overline{E} + \overline{v} \times \overline{B}\right)$$

Also show that

$$\nabla \times \overline{H} = \sigma \overline{E}$$

$$R = \frac{1}{\sigma}\frac{l}{S}$$

the symbols have their usual meanings.

(b) For a space-charge limited diode show that $J = \frac{4\varepsilon_0}{9d^2}\sqrt{\frac{2e}{m}}\,V_0^{3/2}$

The symbols have their usual meanings.

## SECTION – B

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

The figures in the margin indicate full marks.

5. (a) Describe Joule's law taking the example of a conductor of uniform cross-sectional area. Express the law in terms of current Density. Prove that divergence of steady current density is zero. **(12)**

(b) Show that the volume charge density in the interior of a conductor decays exponentially with time. **(08)**

(c) A metallic conductor of rectangular section is in the shape of a circular bow with its centre at the origin. It extends from $\phi = \phi_1$ to $\phi = \phi_2$ in cylindrical co-ordinate system as shown in Fig. Q. 5(c). The inner and outer radii of the bow are a and b respectively, and thickness in the z- direction is c. Calculate resistance of the conductor and power loss. **(15)**

6. (a) State and explain Poynting theorem. The electric field intensity of a linearly polarized uniform plane wave propagating in the +z direction in a good conductor is $\vec{E} = E_0 e^{j(wt - \beta z)}\hat{a}_x$. Find the expression for the average power density transmitted by the uniform plane wave. Make necessary assumptions if required. **(18)**

Contd .......... P/3

**EEE 209**

**Contd Q. No. 6**

(b) A 50 MHz uniform plane wave travelling in a medium $(\varepsilon_r = 16,\ \mu_r = 1.0$ and $\sigma = 0.02\ S/m)$ strikes normally to the surface of another medium $(\varepsilon_r = 25,\ \mu_r = 1$ and *and* $\sigma = 0.2\ S/m)$. If the amplitude of the incident electric field intensity at the interface is 10 V/m, determine the average power density of the transmitted wave. **(17)**

7. (a) Derive Maxwell's equation in differential, integral and phasor form for time varying fields. Briefly explain the concept of displacement current. Justify that "the displacement current is zero in a perfect conductor and the conduction current is zero in a perfect dielectric". **(15)**

(b) The conducting bar of length $l$ is parallel to the x-axis and it moves between two conducting guides in y- direction at a constant velocity V in a uniform magnetic field as shown in the Fig. Q. 7(b). The flux density is in z- direction and it varies sinusoidally with time given by $B(t) = B_o \sin\omega t$. A high resistance voltmeter is connected between the rails at y = 0 to complete the loop. Find the voltage induced in the coil if $l$ = 0.25 m, V = 12.0 m/s, Loop area S = 0.3 $m^2$, $B_o$ = 0.16 T, f = 10 Hz. Make necessary assumption as required. **(15)**

(c) Show that in a good conductor the skin depth δ is always much shorter than the wave length. **(5)**

8. (a) What is polarization? Describe the linear and circular polarization of a plane electromagnetic wave. **(10)**

(b) Determine the polarization of the wave if the electric field intensity in a region is given by **(12)**

$$\vec{E} = (3\hat{a}_x + j4\hat{a}_y)e^{-0.2z}e^{-j0.5z}\ V/m.$$

(c) A plane wave in free space with $E = 3.6\cos(\omega t - 3X)\hat{a}_y\ V/m$ is incident normally on an interface at X = 0. If a loss less medium with $\sigma = 0$, $\varepsilon_r = 12.5$ exists for $X \geq 0$ and the Reflected wave has $H_r = -1.2\cos(\omega t + 3X)\hat{a}_z\ mA/m$, find $\mu_2, \eta_2, \Gamma$ and the standing wave ratio (S). **(13)**

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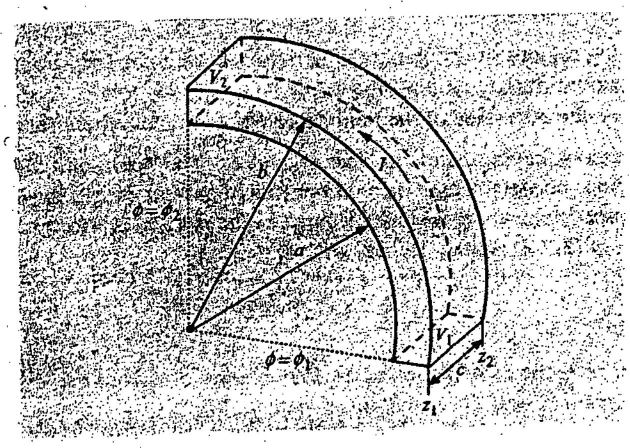


Fig. for Q. 5 (c)

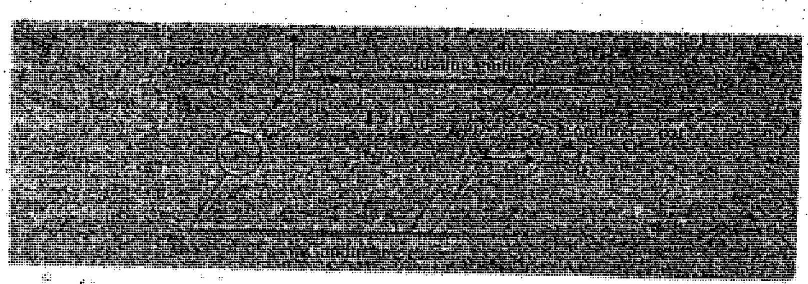

Fig. for Q. 7 (b)

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**L-2/T-2/EEE** **Date : 20/11/2012**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-2 B. Sc. Engineering Examinations 2010-2011

Sub : **EEE 207** (Electronics II)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

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

1. (a) What are the characteristics of an ideal OP - AMP? **(6)**

(b) Draw the circuit diagram whose output voltage is directly proportional to the logarithm of its input voltage. ~~Also derive the expression of its input voltage.~~ Also derive the expression of its output voltage. **(10)**

(c) Determine the value of 'R' for the maximum compensation of the input offset current effect on output voltage for the circuit given in Fig. for Q. 1(c). **(6)**

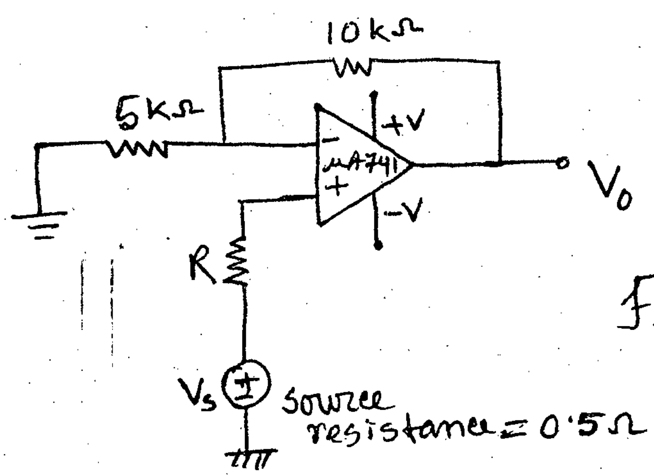


Fig. for Q. 1(c)

(d) Using ideal Op-Amps, design a circuit that will take $v_1$, $v_2$ and $v_3$ as inputs and will produce the following output. **(13)**

$$v_{out} = 10\ v_1 - 10\frac{dv_2}{dt} - 2\int v_3 dt$$

2. (a) Discuss the effects of positive and negative input bias currents on output voltage of an Op-Amp. **(12)**

(b) The Slew rate for a μA741 Op-Amp is 0.5 V/μs. At what maximum frequency can one get an undistorted sine wave output voltage of 10 V peak? **(5)**

(c) How does a Schmitt-trigger circuit reduce the effect of noise? - explain with appropriate sketch. **(11)**

(d) Calculate the load current ($I_L$) in the circuit given in Fig. for Q. 2(d). **(7)**

Contd ......... P/2

**EEE 207**

**Contd ... Q. No. 2(d)**

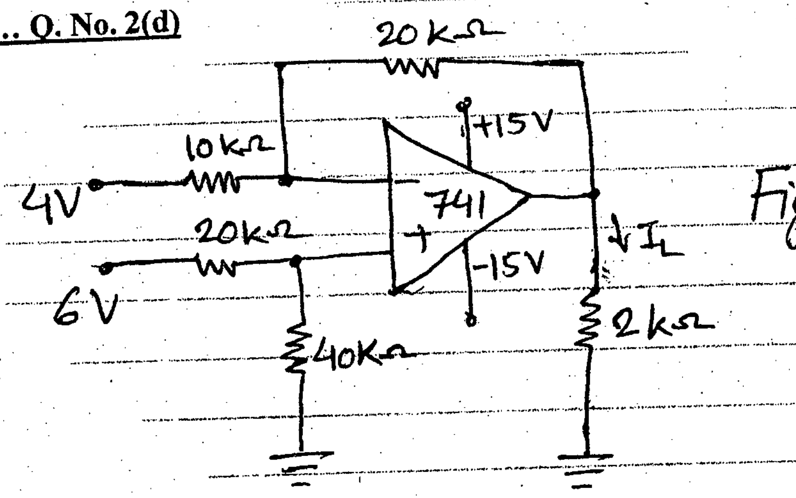


Fig. for Q. 2(d)

**(15)**

3. (a) A particular amplifier has a voltage transfer function,

$$T(S)=\frac{100s^2\left(1+s/10^3\right)}{\left(1+s/10\right)\left(1+s/10^2\right)\left(1+s/10^4\right)}$$

Sketch a Bode plot (on graph paper) for the magnitude response. From the plot, determine the approximate value of voltage gain in dB at $\omega = 10^3$ and $10^5$ rad/sec.

What is the exact value of voltage gain at $\omega = 10^5$ rad/sec?

(b) Select appropriate values for the coupling capacitors '$C_{c1}$; and '$C_{c2}$' and the bypass capacitor '$C_s$' of the amplifier given in Fig. for Q. 3(b). So that the low frequency response will be dominated by a pole at 100 Hz. **(20)**

Given that $V_{DD}$ = 20 V, R = 100 kΩ, $R_{G1}$ = 1.4 MΩ, $R_{G2}$ = 0.6 MΩ, $R_s$ = 3.5 kΩ, $R_D$ = 5 kΩ, $r_0 = \infty$, $R_L$ = 10 kΩ, and $g_m$ = 4mA/V.

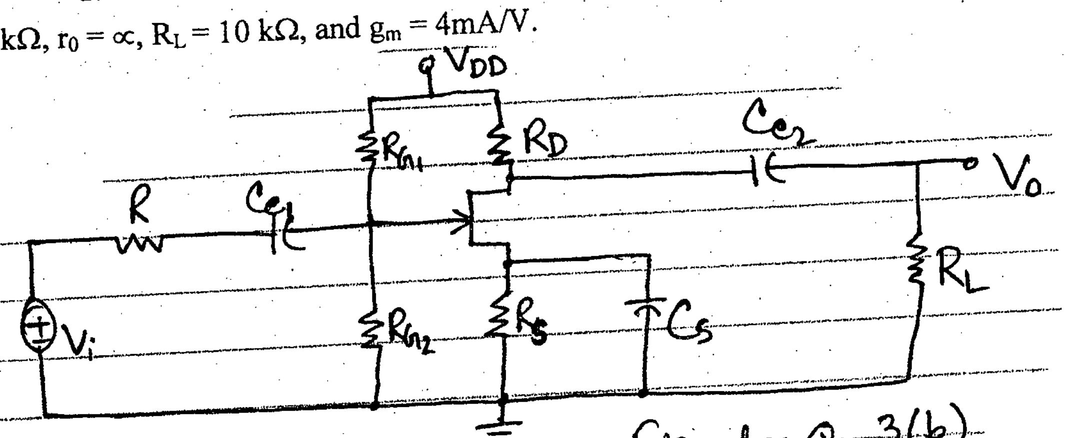


Fig. for Q. 3(b)

4. (a) With necessary diagram, derive the expressions of input resistance, ($R_{if}$) and output resistance ($R_{of}$) of a voltage shunt feedback amplifier. **(17)**

(b) Calculate the voltage gain $A_{vf}$, input resistance $R_{if}$ and output resistance, $R_{of}'$ for the circuit given in Fig. for Q. 4(b). Given that, $h_{ie}$ = 1k, $h_{fe}$ = 100, while $h_{re}$ and $h_{oe}$ are negligible. **(18)**

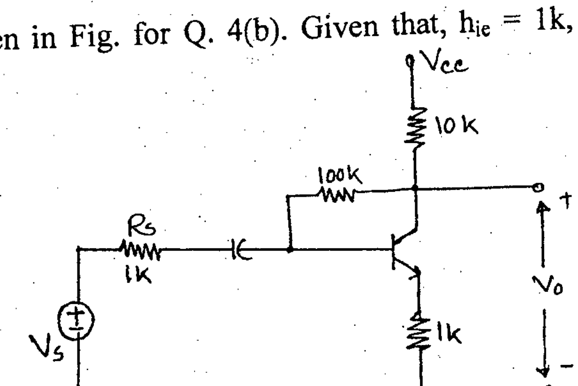


Fig. for Q. 4(b)

**EEE 207**

**SECTION – B**

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

5. (a) Draw the circuit diagram of a Wein-Bridge oscillator and derive the expression for oscillating frequency. Make appropriate assumption if necessary. **(12)**

(b) Design a transformer coupled EF amplifier to drive an 8 Ω load if $V_{cc}$ = 20 V, $V_{BE}$ = 0.7 V, β = 100, $R_{in}$ = 2 k Ω and the transformer has a turns ratio of 10 : 1. Determine the current gain, output power and maximum undistorted output voltage swing. **(12)**

(c) A bandpass filter has a resonant frequency of 950 Hz and a bandwidth of 2700 Hz. Find its lower and upper cut off frequencies. Also, calculate the quality factor of the filter and comment on whether the filter is narrowband or wideband. **(11)**

6. (a) Draw the circuit diagram of the Hartley oscillator. Derive the expression for oscillating frequency and the condition for sustainable oscillation. **(12)**

(b) Design a complementary-symmetry push pull diode-compensated class-B amplifier to derive a 4Ω load to ± 3 V. Assume transistor β = 100 and $V_{BE}$ = ± 0.7 V. The diodes have forward resistance of 10 Ω. Determine all quiescent voltages and currents for $V_{cc}$ = 16 V. Calculate the maximum power delivered by the power supply, the power delivered to the load and the power ratings of the transistors to be used. **(13)**

(c) Octave equalizers have resonant frequencies at approximately 32, 64, 128, 250, 500, 1000, 2000, 4000, 8000 and 16000 Hz. Q of each filter is chosen to have a value of 2.0. With a neat diagram, design an unity-gain filter to select the sixth octave. **(10)**

7. (a) For a transistor phase shift oscillator, derive the expression for oscillating frequency and condition for sustainable oscillation. 12 ~~**(10)**~~

(b) With necessary neat diagrams, derive the expression for the maximum power conversion efficiency of a transformer coupled class-A power amplifier. 10

(c) Draw the generalized circuit diagram of a – 60 dB/decade lowpass filter. Prove that

$$R = \frac{1}{\omega_c C_3}$$

where, symbols bear their usual meanings. **(13)**

8. (a) Describe the operating principle for crystal oscillator. Draw the equivalent circuit diagram and derive the expression for crystal impedance in terms of series and parallel resonant frequencies. **(11)**

**EEE 207**

**Contd ... Q. No. 8**

(b) With necessary neat diagram(s), derive the expressions for input resistance and current gain for a diode-compensated complementary-symmetry class-B power amplifier. **(13)**

(c) Draw the generalized circuit diagram of a – 40 dB/decade lowpass filter and prove that

$$R = \frac{1}{\sqrt{2}\omega_c C_1}$$

where the symbols bear their usual meanings. **(11)**

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L-2/T-2/EEE Date : 18/12/2012

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-2 B. Sc. Engineering Examinations 2010-2011

Sub : **EEE 205** (Energy Conversion - II)

Full Marks: 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

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## SECTION – A

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

The questions are of equal value.

1. (a) Describe with necessary diagrams the brushless systems of excitation of a synchronous generator. Compare these systems from the viewpoint of their advantages and disadvantages.

(b) A 2300 V, 1000 KVA, 0.8 pf lagging, 50 Hz, two-pole, Y-connected synchronous generator has a synchronous reactance of 1.1 Ω and armature resistance of 0.15 Ω. Its friction and windage losses are 24 kW and its core losses are 18 kW. The field circuit has a dc voltage of 200 V. The open circuit characteristic of this generator is given below:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Field current, A | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Open circuit terminal voltage, V | 0 | 650 | 1300 | 1800 | 2200 | 2500 | 2690 | 2750 | 2850 | 2870 | 2900 |

Assume that the field current of the generator is adjusted to achieve rated voltage of 2300 V at full-load condition. Find (i) the efficiency of the generator at rated load, (ii) the voltage regulation of the generator if it is loaded to rated KVA with 0.8 pf lagging load, (iii) the voltage regulation of the generator if it is loaded to rated KVA with 0.8 pf leading load.

2. (a) Explain how the synchronous generator model parameters are found from tests. Explain why the short-circuit characteristic of a synchronous generator is a straight line. Using phasor diagrams explain the effects of load changes having different power factors on a synchronous generator operating alone.

(b) Explain the procedure of paralleling of synchronous generator to the bus-bars by using lamps. What is a phase sequence indicator? How synchroscope can be used for paralleling of generators? Explain the Frequency-Power and Voltage-Reactive Power characteristics of a generator set.

3. (a) Explain how synchronous motor can be used for power factor correction of the supply system. Explain the methods of starting of synchronous motor by changing frequency and by using Amortisseur windings.

Contd .......... P/2

**EEE 205**

**Contd ... Q. No. 3**

(b) A Y-connected synchronous machine has a synchronous reactance of 2.0 Ω per phase and armature resistance of 0.4 Ω per phase. If the line to line values of internal e.m.f. and terminal voltage are $E_A = 460\angle -8^\circ$ V and $V_T = 480\angle 0^\circ$ V, is this machine a motor or a generator? How much power (P) this machine is consuming from or supplying to the electrical system? How much reactive power (Q) is this machine consuming from or supplying to the electrical system?

4. (a) What are the V-curves of synchronous motor? Draw these curves and explain their shapes. Explain the terms over and under excitation of synchronous motor. By using phasor diagram explain the effects of load changes on a synchronous motor.
(b) Explain the photovoltaic effect in a semiconductor p-n junction. Write the expression of current density in junction in terms of its components. Derive the expressions of open-circuit voltage, voltage and current density of solar cell at maximum power density. Draw and explain the equivalent circuit of solar cell. What is fill factor?

**SECTION – B**

There are **FOUR** questions in this Section. Answer any **THREE**.
The figures in the margin indicate full marks.

5. (a) Explain with neat sketches what happens to magnetic neutral axis of a dc motor due to armature reaction. **(15)**
(b) Explain with neat sketches how compensating winding solves the problem of shifting of magnetic neutral axis. What are the disadvantages of using compensating windings? **(10)**
(c) An eight-pole, 25-kW, 120-V dc generator has a duplex lap-would armature which has 64 coils with 16 turns per coil. Its rated speed is 2400 r/min. **(10)**
   (i) How much flux per pole is required to produce the rated voltage in this generator at no load conditions?
   (ii) What is the current per path in the armature of this generator at the rated load?
   (iii) What is the induced torque in this machine at the rated load?
   (iv) How many brushes must this motor have? How wide must each one be?
   (v) If the resistance of this winding is 0.011 Ω per turn, what is the armature resistance $R_A$ of this machine?

6. (a) Describe the operation of a dc motor starting circuit using rising time delay relays to cut out the starting resistor. **(13)**
(b) A 100-hp, 250-V, 350-A shunt dc motor has an armature resistance of 0.05 Ω. It is desired to design a starter circuit for this motor which will limit the maximum starting current to twice its rated value and which will switch out sections of resistance as the armature current falls to its rated value. **(12)**

Contd .......... P/3

## EEE 205

**Contd ... Q. No. 6(b)**

(i) How many stages of starting resistance will be required to limit the current to the range specified?

(ii) What must the value of each segment of the resistor be? At what voltage should each stage of the starting resistance be cut out? **(10)**

(c) Describe the effect of an open field circuit in a shunt dc motor. **(10)**

7. (a) Describe the terminal characteristic of a shunt dc motor. **(18)**

(b) Explain with necessary equations what happens when the speed of a shunt dc motor is controlled by changing the field resistance. **(7)**

(c) Compare the torque-speed characteristic of a cumulatively compounded dc motor to those of series and shunt motors with the same full load rating. **(10)**

8. (a) Explain with necessary figures how voltage builds up in a shunt dc generator. **(10)**

(b) Describe different types of wind turbine briefly. Show the typical wind speed-power curve of a wind turbine. Show the typical power density-duration curve of a wind turbine.

(c) A 15-hp, 230-V, 1800 r/min shunt dc motor has a full-load armature current of 60 A when operating at rated conditions. The armature resistance of the motor is $R_A = 0.15\ \Omega$ and the field resistance $R_F = 80\ \Omega$. The adjustable resistance in the field circuit $R_{adj}$ may be varied over the range from 0 to 200 Ω and is currently set to 90 Ω. Armature reaction may be ignored in this machine. The magnetization curve for this motor taken at a speed of 1800 r/min. is given in tabular form below: **(15)**

| $E_A$, V | 8.5 | 150 | 180 | 215 | 226 | 242 |
|---|---|---|---|---|---|---|
| $I_F$, A | 0.00 | 0.80 | 1.00 | 1.28 | 1.44 | 2.88 |

(i) What is the speed of this motor when it is running at the rated conditions specified above?

(ii) The output power from the motor is 7.5 hp at rated conditions. What is the output torque of the motor?

(iii) What are the copper losses and rotational losses in the motor at full load (ignore stray losses)?

(iv) What is the efficiency of the motor at full load?

(v) If the motor is now unloaded with no changes in terminal voltage or $R_{adj}$. What is the no load speed of the motor?

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**L-2/T-2/EEE** **Date : 08/01/2013**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-2 B. Sc. Engineering Examinations 2010-2011

Sub : **MATH 357** (Probability and Statistics)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

## SECTION – A

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

1. (a) If the values of a series are in geometric progression, obtain the arithmetic mean (AM), geometric mean (GM) and harmonic mean (HM) and hence show that AM × HM = $GM^2$. **(10)**

(b) The coefficient of skewness of a set of data is 0.32. Its standard deviation and mean are 6.5 and 29.6 respectively. Find median, mode and comment on the shape of the distribution with figure. **(10)**

(c) An electrical circuit system is given in Fig. 1. The probability of working of each component are also shown in Fig. 1. **(15)**

(i) What is the probability that the entire system works?

(ii) Given that the system works, what is the probability that the component A is not working?

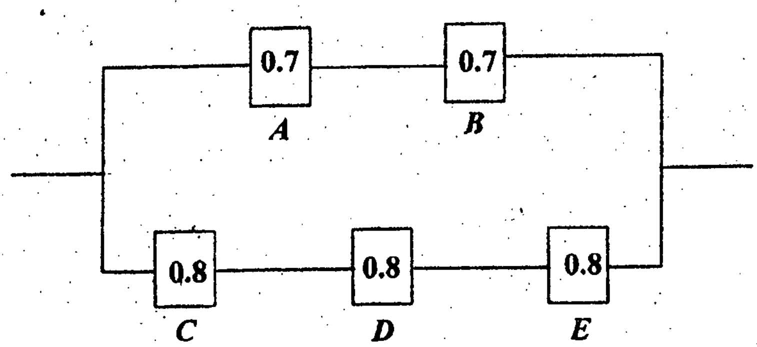



**Fig. 1**

2. (a) The probability distribution of X, the number of imperfections per 10 meters of a synthetic fabric in continuous rolls of uniform width, is given by

| x | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| f(x) | 0.41 | 0.37 | 0.16 | 0.05 | 0.01 |

Construct the cumulative distribution function F(x) and also find $P(x > 2)$. **(12)**

(b) A and B in turns toss an ordinary die for a prize of Tk. 1000/-. The first to toss a 'six' wins. If A has first throw, what is his expectation? **(10)**

(c) Show that central moments are independent of the origin but dependent on scale and hence verify this claim for the first four moments about the mean using the values 20, 25, 30, 40, 50 of the variable X. **(13)**

Contd .......... P/2

## MATH 357(EEE)

3. (a) Suppose X and Y have a continuous joint distribution for which the joint probability density function is $f(x,y) = \begin{cases} x+y; & 0<x<1, 0<y<1 \\ 0, & otherwise. \end{cases}$

Calculate var (Y|X). **(15)**

(b) Telephone calls arrive at a switch board at a mean rate of 0.5 calls per minute. Find the probability that two calls will arrive in a particular five-minute period. **(10)**

(c) Find the mean and variance of Gaussian distribution. **(10)**

4. (a) Suppose that the measured voltage in a certain electric circuit has a normal distribution with $\mu = 122$ and $\sigma = 2$. If three independent measurements of the voltage are made, what is the probability that all three measurements will lie between 117 and 121? (Necessary chart 1 is attached) **(15)**

(b) Obtain the first four raw and central moments of binomial distribution. **(12)**

(c) A bag contains 3 red, 4 white, 2 blue and 5 green balls, 20 balls are drawn at random from it one after another with replacement. What is the probability of obtaining 5 balls of each colour? **(8)**

### SECTION – B

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

5. (a) A population consists of five numbers 2, 3, 6, 8 and 11. Consider all possible samples of size 2 that can be drawn without replacement from this population. Find the standard deviation of sampling distribution of variances. **(10)**

(b) The masses of 1500 rivets are normally distributed, with mean of 22.40 g and a standard deviation of 0.048 g. If 300 random samples of size 36 are drawn from this population, determine the expected mean and standard deviation of sampling distribution of means if the sampling is done (i) with replacement and (ii) without replacement. **(15)**

(c) The weights of packages received by a departmental store have a mean of 150 kg and a standard deviation of 25 kg. What is the probability that the 25 packages received at random and loaded on an elevator will exceed the specified safety limit of the elevator, listed as 4100 kg? (Necessary chart-2 is attached) **(10)**

6. (a) Certain tubes manufactured by a company have a mean life time of 800 h and standard deviation of 60 h. Find the probability that a random sample of 16 tubes taken from the group will have a mean life time of (i) between 790 and 810 h (ii) less than 785 h. (Necessary chart-2 is attached) **(14)**

**MATH 357(EEE)**

**Contd ... Q. No. 6**

(b) Measurements of the diameters of a random sample of 200 ball bearings made by a certain machine during 1 week showed a mean of 8.24 mm and a standard deviation of 0.42 mm. Find the (i) 95% and (ii) 99 % confidence limits for the mean diameter of all the ball bearings. **(7)**

(c) From the following data, obtain the line of regression of X on Y and Y on X and estimate the value X when Y = 9. Also calculate regression coefficient. **(14)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| X: | 2 | 6 | 8 | 11 | 13 | 13 | 13 | 14 |
| Y: | 8 | 6 | 10 | 12 | 12 | 14 | 14 | 20 |

7. (a) For certain X and Y series, the lines of regression of Y on X and X on Y are respectively $6Y = 5X + 90$ and $15X = 8Y + 130$. The standard deviation of X values is 4. Find (i) Mean of X values (ii) Mean of Y values (iii) Standard deviation of Y values (iv) Coefficient of correlation between X and Y. **(20)**

(b) A bulb manufacturing company claims that the average longevity of their bulb is 4 years with a standard deviation 0.16 years. A random sample of 40 bulbs gave mean longevity of 3.45 years. Does the sample mean justify the claim of the manufacturer? (Use a 5 percent level of significance) **(15)**

8. (a) The following table gives the number of accidents that occur during various days of the week. Find whether the accidents are uniformly distributed over the week using a significance level of 0.05. **(15)**

| Days | Sun. | Mon. | Tues. | Wed. | Thurs. | Fri. | Sat. | Total |
|---|---|---|---|---|---|---|---|---|
| No. of Accidents | 14 | 16 | 8 | 12 | 11 | 9 | 14 | 84 |

(Necessary chart-3 is attached)

(b) A company wishes to purchase one of five different machines: A, B, C, D or E. In an experiment designed to test whether there is a difference in the machines' performance, each of five experienced operators work on each of the machines for equal times. Table below shows the number of units produced per machine. Test the hypothesis that there is no difference between the machines at significance level of 0.05. **(20)**

| | | | | | |
|---|---|---|---|---|---|
| A | 68 | 72 | 77 | 42 | 53 |
| B | 72 | 53 | 63 | 53 | 48 |
| C | 60 | 82 | 64 | 75 | 72 |
| D | 48 | 61 | 57 | 64 | 50 |
| E | 64 | 65 | 70 | 68 | 53 |

(Necessary chart-4 is attached)

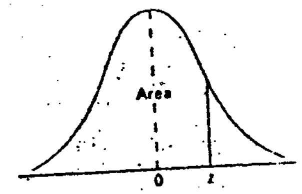



**TABLE A.3** Areas Under the Normal Curve

| z | .00 | .01 | .02 | .03 | .04 | .05 | .06 | .07 | .08 | .09 |
|---|---|---|---|---|---|---|---|---|---|---|
| −3.4 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.0002 |
| −3.3 | 0.0005 | 0.0005 | 0.0005 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0003 |
| −3.2 | 0.0007 | 0.0007 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0006 | 0.0005 | 0.0005 | 0.0005 |
| −3.1 | 0.0010 | 0.0009 | 0.0009 | 0.0009 | 0.0008 | 0.0008 | 0.0008 | 0.0008 | 0.0007 | 0.0007 |
| −3.0 | 0.0013 | 0.0013 | 0.0013 | 0.0012 | 0.0012 | 0.0011 | 0.0011 | 0.0011 | 0.0010 | 0.0010 |
| −2.9 | 0.0019 | 0.0018 | 0.0018 | 0.0017 | 0.0016 | 0.0016 | 0.0015 | 0.0015 | 0.0014 | 0.0014 |
| −2.8 | 0.0026 | 0.0025 | 0.0024 | 0.0023 | 0.0023 | 0.0022 | 0.0021 | 0.0021 | 0.0020 | 0.0019 |
| −2.7 | 0.0035 | 0.0034 | 0.0033 | 0.0032 | 0.0031 | 0.0030 | 0.0029 | 0.0028 | 0.0027 | 0.0026 |
| −2.6 | 0.0047 | 0.0045 | 0.0044 | 0.0043 | 0.0041 | 0.0040 | 0.0039 | 0.0038 | 0.0037 | 0.0036 |
| −2.5 | 0.0062 | 0.0060 | 0.0059 | 0.0057 | 0.0055 | 0.0054 | 0.0052 | 0.0051 | 0.0049 | 0.0048 |
| −2.4 | 0.0082 | 0.0080 | 0.0078 | 0.0075 | 0.0073 | 0.0071 | 0.0069 | 0.0068 | 0.0066 | 0.0064 |
| −2.3 | 0.0107 | 0.0104 | 0.0102 | 0.0099 | 0.0096 | 0.0094 | 0.0091 | 0.0089 | 0.0087 | 0.0084 |
| −2.2 | 0.0139 | 0.0136 | 0.0132 | 0.0129 | 0.0125 | 0.0122 | 0.0119 | 0.0116 | 0.0113 | 0.0110 |
| −2.1 | 0.0179 | 0.0174 | 0.0170 | 0.0166 | 0.0162 | 0.0158 | 0.0154 | 0.0150 | 0.0146 | 0.0143 |
| −2.0 | 0.0228 | 0.0222 | 0.0217 | 0.0212 | 0.0207 | 0.0202 | 0.0197 | 0.0192 | 0.0188 | 0.0183 |
| −1.9 | 0.0287 | 0.0281 | 0.0274 | 0.0268 | 0.0262 | 0.0256 | 0.0250 | 0.0244 | 0.0239 | 0.0233 |
| −1.8 | 0.0359 | 0.0352 | 0.0344 | 0.0336 | 0.0329 | 0.0322 | 0.0314 | 0.0307 | 0.0301 | 0.0294 |
| −1.7 | 0.0446 | 0.0436 | 0.0427 | 0.0418 | 0.0409 | 0.0401 | 0.0392 | 0.0384 | 0.0375 | 0.0367 |
| −1.6 | 0.0548 | 0.0537 | 0.0526 | 0.0516 | 0.0505 | 0.0495 | 0.0485 | 0.0475 | 0.0465 | 0.0455 |
| −1.5 | 0.0668 | 0.0655 | 0.0643 | 0.0630 | 0.0618 | 0.0606 | 0.0594 | 0.0582 | 0.0571 | 0.0559 |
| −1.4 | 0.0808 | 0.0793 | 0.0778 | 0.0764 | 0.0749 | 0.0735 | 0.0722 | 0.0708 | 0.0694 | 0.0681 |
| −1.3 | 0.0968 | 0.0951 | 0.0934 | 0.0918 | 0.0901 | 0.0885 | 0.0869 | 0.0853 | 0.0838 | 0.0823 |
| −1.2 | 0.1151 | 0.1131 | 0.1112 | 0.1093 | 0.1075 | 0.1056 | 0.1038 | 0.1020 | 0.1003 | 0.0985 |
| −1.1 | 0.1357 | 0.1335 | 0.1314 | 0.1292 | 0.1271 | 0.1251 | 0.1230 | 0.1210 | 0.1190 | 0.1170 |
| −1.0 | 0.1587 | 0.1562 | 0.1539 | 0.1515 | 0.1492 | 0.1469 | 0.1446 | 0.1423 | 0.1401 | 0.1379 |
| −0.9 | 0.1841 | 0.1814 | 0.1788 | 0.1762 | 0.1736 | 0.1711 | 0.1685 | 0.1660 | 0.1635 | 0.1611 |
| −0.8 | 0.2119 | 0.2090 | 0.2061 | 0.2033 | 0.2005 | 0.1977 | 0.1949 | 0.1922 | 0.1894 | 0.1867 |
| −0.7 | 0.2420 | 0.2389 | 0.2358 | 0.2327 | 0.2296 | 0.2266 | 0.2236 | 0.2206 | 0.2177 | 0.2148 |
| −0.6 | 0.2743 | 0.2709 | 0.2676 | 0.2643 | 0.2611 | 0.2578 | 0.2546 | 0.2514 | 0.2483 | 0.2451 |
| −0.5 | 0.3085 | 0.3050 | 0.3015 | 0.2981 | 0.2946 | 0.2912 | 0.2877 | 0.2843 | 0.2810 | 0.2776 |
| −0.4 | 0.3446 | 0.3409 | 0.3372 | 0.3336 | 0.3300 | 0.3264 | 0.3228 | 0.3192 | 0.3156 | 0.3121 |
| −0.3 | 0.3821 | 0.3783 | 0.3745 | 0.3707 | 0.3669 | 0.3632 | 0.3594 | 0.3557 | 0.3520 | 0.3483 |
| −0.2 | 0.4207 | 0.4168 | 0.4129 | 0.4090 | 0.4052 | 0.4013 | 0.3974 | 0.3936 | 0.3897 | 0.3859 |
| −0.1 | 0.4602 | 0.4562 | 0.4522 | 0.4483 | 0.4443 | 0.4404 | 0.4364 | 0.4325 | 0.4286 | 0.4247 |
| −0.0 | 0.5000 | 0.4960 | 0.4920 | 0.4880 | 0.4840 | 0.4801 | 0.4761 | 0.4721 | 0.4681 | 0.4641 |

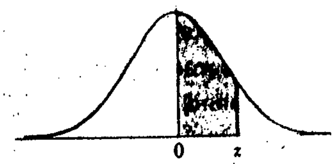
Chart 1 for Q. no. 4 (a) (Math 357)

**TABLE A.3** (continued) Areas Under the Normal Curve

| z | .00 | .01 | .02 | .03 | .04 | .05 | .06 | .07 | .08 | .09 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.5000 | 0.5040 | 0.5080 | 0.5120 | 0.5160 | 0.5199 | 0.5239 | 0.5279 | 0.5319 | 0.5359 |
| 0.1 | 0.5398 | 0.5438 | 0.5478 | 0.5517 | 0.5557 | 0.5596 | 0.5636 | 0.5675 | 0.5714 | 0.5753 |
| 0.2 | 0.5793 | 0.5832 | 0.5871 | 0.5910 | 0.5948 | 0.5987 | 0.6026 | 0.6064 | 0.6103 | 0.6141 |
| 0.3 | 0.6179 | 0.6217 | 0.6255 | 0.6293 | 0.6331 | 0.6368 | 0.6406 | 0.6443 | 0.6480 | 0.6517 |
| 0.4 | 0.6554 | 0.6591 | 0.6628 | 0.6664 | 0.6700 | 0.6736 | 0.6772 | 0.6808 | 0.6844 | 0.6879 |
| 0.5 | 0.6915 | 0.6950 | 0.6985 | 0.7019 | 0.7054 | 0.7088 | 0.7123 | 0.7157 | 0.7190 | 0.7224 |
| 0.6 | 0.7257 | 0.7291 | 0.7324 | 0.7357 | 0.7389 | 0.7422 | 0.7454 | 0.7486 | 0.7517 | 0.7549 |
| 0.7 | 0.7580 | 0.7611 | 0.7642 | 0.7673 | 0.7704 | 0.7734 | 0.7764 | 0.7794 | 0.7823 | 0.7852 |
| 0.8 | 0.7881 | 0.7910 | 0.7939 | 0.7967 | 0.7995 | 0.8023 | 0.8051 | 0.8078 | 0.8106 | 0.8133 |
| 0.9 | 0.8159 | 0.8186 | 0.8212 | 0.8238 | 0.8264 | 0.8289 | 0.8315 | 0.8340 | 0.8365 | 0.8389 |
| 1.0 | 0.8413 | 0.8438 | 0.8461 | 0.8485 | 0.8508 | 0.8531 | 0.8554 | 0.8577 | 0.8599 | 0.8621 |
| 1.1 | 0.8643 | 0.8665 | 0.8686 | 0.8708 | 0.8729 | 0.8749 | 0.8770 | 0.8790 | 0.8810 | 0.8830 |
| 1.2 | 0.8849 | 0.8869 | 0.8888 | 0.8907 | 0.8925 | 0.8944 | 0.8962 | 0.8980 | 0.8997 | 0.9015 |
| 1.3 | 0.9032 | 0.9049 | 0.9066 | 0.9082 | 0.9099 | 0.9115 | 0.9131 | 0.9147 | 0.9162 | 0.9177 |
| 1.4 | 0.9192 | 0.9207 | 0.9222 | 0.9236 | 0.9251 | 0.9265 | 0.9278 | 0.9292 | 0.9306 | 0.9319 |
| 1.5 | 0.9332 | 0.9345 | 0.9357 | 0.9370 | 0.9382 | 0.9394 | 0.9406 | 0.9418 | 0.9429 | 0.9441 |
| 1.6 | 0.9452 | 0.9463 | 0.9474 | 0.9484 | 0.9495 | 0.9505 | 0.9515 | 0.9525 | 0.9535 | 0.9545 |
| 1.7 | 0.9554 | 0.9564 | 0.9573 | 0.9582 | 0.9591 | 0.9599 | 0.9608 | 0.9616 | 0.9625 | 0.9633 |
| 1.8 | 0.9641 | 0.9649 | 0.9656 | 0.9664 | 0.9671 | 0.9678 | 0.9686 | 0.9693 | 0.9699 | 0.9706 |
| 1.9 | 0.9713 | 0.9719 | 0.9726 | 0.9732 | 0.9738 | 0.9744 | 0.9750 | 0.9756 | 0.9761 | 0.9767 |
| 2.0 | 0.9772 | 0.9778 | 0.9783 | 0.9788 | 0.9793 | 0.9798 | 0.9803 | 0.9808 | 0.9812 | 0.9817 |
| 2.1 | 0.9821 | 0.9826 | 0.9830 | 0.9834 | 0.9838 | 0.9842 | 0.9846 | 0.9850 | 0.9854 | 0.9857 |
| 2.2 | 0.9861 | 0.9864 | 0.9868 | 0.9871 | 0.9875 | 0.9878 | 0.9881 | 0.9884 | 0.9887 | 0.9890 |
| 2.3 | 0.9893 | 0.9896 | 0.9898 | 0.9901 | 0.9904 | 0.9906 | 0.9909 | 0.9911 | 0.9913 | 0.9916 |
| 2.4 | 0.9918 | 0.9920 | 0.9922 | 0.9925 | 0.9927 | 0.9929 | 0.9931 | 0.9932 | 0.9934 | 0.9936 |
| 2.5 | 0.9938 | 0.9940 | 0.9941 | 0.9943 | 0.9945 | 0.9946 | 0.9948 | 0.9949 | 0.9951 | 0.9952 |
| 2.6 | 0.9953 | 0.9955 | 0.9956 | 0.9957 | 0.9959 | 0.9960 | 0.9961 | 0.9962 | 0.9963 | 0.9964 |
| 2.7 | 0.9965 | 0.9966 | 0.9967 | 0.9968 | 0.9969 | 0.9970 | 0.9971 | 0.9972 | 0.9973 | 0.9974 |
| 2.8 | 0.9974 | 0.9975 | 0.9976 | 0.9977 | 0.9977 | 0.9978 | 0.9979 | 0.9979 | 0.9980 | 0.9981 |
| 2.9 | 0.9981 | 0.9982 | 0.9982 | 0.9983 | 0.9984 | 0.9984 | 0.9985 | 0.9985 | 0.9986 | 0.9986 |
| 3.0 | 0.9987 | 0.9987 | 0.9987 | 0.9988 | 0.9988 | 0.9989 | 0.9989 | 0.9989 | 0.9990 | 0.9990 |
| 3.1 | 0.9990 | 0.9991 | 0.9991 | 0.9991 | 0.9992 | 0.9992 | 0.9992 | 0.9992 | 0.9993 | 0.9993 |
| 3.2 | 0.9993 | 0.9993 | 0.9994 | 0.9994 | 0.9994 | 0.9994 | 0.9994 | 0.9995 | 0.9995 | 0.9995 |
| 3.3 | 0.9995 | 0.9995 | 0.9995 | 0.9996 | 0.9996 | 0.9996 | 0.9996 | 0.9996 | 0.9996 | 0.9997 |
| 3.4 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9998 |

## Appendix II

**Areas Under the Standard Normal Curve from 0 to z**



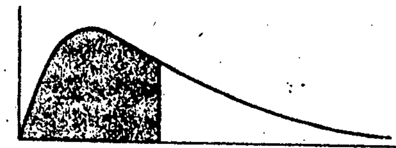

| z | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | .0000 | .0040 | .0080 | .0120 | .0160 | .0199 | .0239 | .0279 | .0319 | .0359 |
| 0.1 | .0398 | .0438 | .0478 | .0517 | .0557 | .0596 | .0636 | .0675 | .0714 | .0754 |
| 0.2 | .0793 | .0832 | .0871 | .0910 | .0948 | .0987 | .1026 | .1064 | .1103 | .1141 |
| 0.3 | .1179 | .1217 | .1255 | .1293 | .1331 | .1368 | .1406 | .1443 | .1480 | .1517 |
| 0.4 | .1554 | .1591 | .1628 | .1664 | .1700 | .1736 | .1772 | .1808 | .1844 | .1879 |
| 0.5 | .1915 | .1950 | .1985 | .2019 | .2054 | .2088 | .2123 | .2157 | .2190 | .2224 |
| 0.6 | .2258 | .2291 | .2324 | .2357 | .2389 | .2422 | .2454 | .2486 | .2518 | .2549 |
| 0.7 | .2580 | .2612 | .2642 | .2673 | .2704 | .2734 | .2764 | .2794 | .2823 | .2852 |
| 0.8 | .2881 | .2910 | .2939 | .2967 | .2996 | .3023 | .3051 | .3078 | .3106 | .3133 |
| 0.9 | .3159 | .3186 | .3212 | .3238 | .3264 | .3289 | .3315 | .3340 | .3365 | .3389 |
| 1.0 | .3413 | .3438 | .3461 | .3485 | .3508 | .3531 | .3554 | .3577 | .3599 | .3621 |
| 1.1 | .3643 | .3665 | .3686 | .3708 | .3729 | .3749 | .3770 | .3790 | .3810 | .3830 |
| 1.2 | .3849 | .3869 | .3888 | .3907 | .3925 | .3944 | .3962 | .3980 | .3997 | .4015 |
| 1.3 | .4032 | .4049 | .4066 | .4082 | .4099 | .4115 | .4131 | .4147 | .4162 | .4177 |
| 1.4 | .4192 | .4207 | .4222 | .4236 | .4251 | .4265 | .4279 | .4292 | .4306 | .4319 |
| 1.5 | .4332 | .4345 | .4357 | .4370 | .4382 | .4394 | .4406 | .4418 | .4429 | .4441 |
| 1.6 | .4452 | .4463 | .4474 | .4484 | .4495 | .4505 | .4515 | .4525 | .4535 | .4545 |
| 1.7 | .4554 | .4564 | .4573 | .4582 | .4591 | .4599 | .4608 | .4616 | .4625 | .4633 |
| 1.8 | .4641 | .4649 | .4656 | .4664 | .4671 | .4678 | .4686 | .4693 | .4699 | .4706 |
| 1.9 | .4713 | .4719 | .4726 | .4732 | .4738 | .4744 | .4750 | .4756 | .4761 | .4767 |
| 2.0 | .4772 | .4778 | .4783 | .4788 | .4793 | .4798 | .4803 | .4808 | .4812 | .4817 |
| 2.1 | .4821 | .4826 | .4830 | .4834 | .4838 | .4842 | .4846 | .4850 | .4854 | .4857 |
| 2.2 | .4861 | .4864 | .4868 | .4871 | .4875 | .4878 | .4881 | .4884 | .4887 | .4890 |
| 2.3 | .4893 | .4896 | .4898 | .4901 | .4904 | .4906 | .4909 | .4911 | .4913 | .4916 |
| 2.4 | .4918 | .4920 | .4922 | .4925 | .4927 | .4929 | .4931 | .4932 | .4934 | .4936 |
| 2.5 | .4938 | .4940 | .4941 | .4943 | .4945 | .4946 | .4948 | .4949 | .4951 | .4952 |
| 2.6 | .4953 | .4955 | .4956 | .4957 | .4959 | .4960 | .4961 | .4962 | .4963 | .4964 |
| 2.7 | .4965 | .4966 | .4967 | .4968 | .4969 | .4970 | .4971 | .4972 | .4973 | .4974 |
| 2.8 | .4974 | .4975 | .4976 | .4977 | .4977 | .4978 | .4979 | .4979 | .4980 | .4981 |
| 2.9 | .4981 | .4982 | .4982 | .4983 | .4984 | .4984 | .4985 | .4985 | .4986 | .4986 |
| 3.0 | .4987 | .4987 | .4987 | .4988 | .4988 | .4989 | .4989 | .4989 | .4990 | .4990 |
| 3.1 | .4990 | .4991 | .4991 | .4991 | .4992 | .4992 | .4992 | .4992 | .4993 | .4993 |
| 3.2 | .4993 | .4993 | .4994 | .4994 | .4994 | .4994 | .4994 | .4995 | .4995 | .4995 |
| 3.3 | .4995 | .4995 | .4995 | .4996 | .4996 | .4996 | .4996 | .4996 | .4996 | .4997 |
| 3.4 | .4997 | .4997 | .4997 | .4997 | .4997 | .4997 | .4997 | .4997 | .4997 | .4998 |
| 3.5 | .4998 | .4998 | .4998 | .4998 | .4998 | .4998 | .4998 | .4998 | .4998 | .4998 |
| 3.6 | .4998 | .4998 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 |
| 3.7 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 |
| 3.8 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 | .4999 |
| 3.9 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 | .5000 |



Chart 2 for Question no 6(a) and 5(c)

## ~~Appendix IV~~

**Percentile Values ($\chi_p^2$)**
**for**
**the Chi-Square Distribution**
**with $\nu$ Degrees of Freedom**
**(shaded area = $p$)**




| $\nu$ | $\chi^2_{.995}$ | $\chi^2_{.99}$ | $\chi^2_{.975}$ | $\chi^2_{.95}$ | $\chi^2_{.90}$ | $\chi^2_{.75}$ | $\chi^2_{.50}$ | $\chi^2_{.25}$ | $\chi^2_{.10}$ | $\chi^2_{.05}$ | $\chi^2_{.025}$ | $\chi^2_{.01}$ | $\chi^2_{.005}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.88 | 6.63 | 5.02 | 3.84 | 2.71 | 1.32 | .455 | .102 | .0158 | .0039 | .0010 | .0002 | .0000 |
| 2 | 10.6 | 9.21 | 7.38 | 5.99 | 4.61 | 2.77 | 1.39 | .575 | .211 | .103 | .0506 | .0201 | .0100 |
| 3 | 12.8 | 11.3 | 9.35 | 7.81 | 6.25 | 4.11 | 2.37 | 1.21 | .584 | .352 | .216 | .115 | .072 |
| 4 | 14.9 | 13.3 | 11.1 | 9.49 | 7.78 | 5.39 | 3.36 | 1.92 | 1.06 | .711 | .484 | .297 | .207 |
| 5 | 16.7 | 15.1 | 12.8 | 11.1 | 9.24 | 6.63 | 4.35 | 2.67 | 1.61 | 1.15 | .831 | .554 | .412 |
| 6 | 18.5 | 16.8 | 14.4 | 12.6 | 10.6 | 7.84 | 5.35 | 3.45 | 2.20 | 1.64 | 1.24 | .872 | .676 |
| 7 | 20.3 | 18.5 | 16.0 | 14.1 | 12.0 | 9.04 | 6.35 | 4.25 | 2.83 | 2.17 | 1.69 | 1.24 | .989 |
| 8 | 22.0 | 20.1 | 17.5 | 15.5 | 13.4 | 10.2 | 7.34 | 5.07 | 3.49 | 2.73 | 2.18 | 1.65 | 1.34 |
| 9 | 23.6 | 21.7 | 19.0 | 16.9 | 14.7 | 11.4 | 8.34 | 5.90 | 4.17 | 3.33 | 2.70 | 2.09 | 1.73 |
| 10 | 25.2 | 23.2 | 20.5 | 18.3 | 16.0 | 12.5 | 9.34 | 6.74 | 4.87 | 3.94 | 3.25 | 2.56 | 2.16 |
| 11 | 26.8 | 24.7 | 21.9 | 19.7 | 17.3 | 13.7 | 10.3 | 7.58 | 5.58 | 4.57 | 3.82 | 3.05 | 2.60 |
| 12 | 28.3 | 26.2 | 23.3 | 21.0 | 18.5 | 14.8 | 11.3 | 8.44 | 6.30 | 5.23 | 4.40 | 3.57 | 3.07 |
| 13 | 29.8 | 27.7 | 24.7 | 22.4 | 19.8 | 16.0 | 12.3 | 9.30 | 7.04 | 5.89 | 5.01 | 4.11 | 3.57 |
| 14 | 31.3 | 29.1 | 26.1 | 23.7 | 21.1 | 17.1 | 13.3 | 10.2 | 7.79 | 6.57 | 5.63 | 4.66 | 4.07 |
| 15 | 32.8 | 30.6 | 27.5 | 25.0 | 22.3 | 18.2 | 14.3 | 11.0 | 8.55 | 7.26 | 6.26 | 5.23 | 4.60 |
| 16 | 34.3 | 32.0 | 28.8 | 26.3 | 23.5 | 19.4 | 15.3 | 11.9 | 9.31 | 7.96 | 6.91 | 5.81 | 5.14 |
| 17 | 35.7 | 33.4 | 30.2 | 27.6 | 24.8 | 20.5 | 16.3 | 12.8 | 10.1 | 8.67 | 7.56 | 6.41 | 5.70 |
| 18 | 37.2 | 34.8 | 31.5 | 28.9 | 26.0 | 21.6 | 17.3 | 13.7 | 10.9 | 9.39 | 8.23 | 7.01 | 6.26 |
| 19 | 38.6 | 36.2 | 32.9 | 30.1 | 27.2 | 22.7 | 18.3 | 14.6 | 11.7 | 10.1 | 8.91 | 7.63 | 6.84 |
| 20 | 40.0 | 37.6 | 34.2 | 31.4 | 28.4 | 23.8 | 19.3 | 15.5 | 12.4 | 10.9 | 9.59 | 8.26 | 7.43 |
| 21 | 41.4 | 38.9 | 35.5 | 32.7 | 29.6 | 24.9 | 20.3 | 16.3 | 13.2 | 11.6 | 10.3 | 8.90 | 8.03 |
| 22 | 42.8 | 40.3 | 36.8 | 33.9 | 30.8 | 26.0 | 21.3 | 17.2 | 14.0 | 12.3 | 11.0 | 9.54 | 8.64 |
| 23 | 44.2 | 41.6 | 38.1 | 35.2 | 32.0 | 27.1 | 22.3 | 18.1 | 14.8 | 13.1 | 11.7 | 10.2 | 9.26 |
| 24 | 45.6 | 43.0 | 39.4 | 36.4 | 33.2 | 28.2 | 23.3 | 19.0 | 15.7 | 13.8 | 12.4 | 10.9 | 9.89 |
| 25 | 46.9 | 44.3 | 40.6 | 37.7 | 34.4 | 29.3 | 24.3 | 19.9 | 16.5 | 14.6 | 13.1 | 11.5 | 10.5 |
| 26 | 48.3 | 45.6 | 41.9 | 38.9 | 35.6 | 30.4 | 25.3 | 20.8 | 17.3 | 15.4 | 13.8 | 12.2 | 11.2 |
| 27 | 49.6 | 47.0 | 43.2 | 40.1 | 36.7 | 31.5 | 26.3 | 21.7 | 18.1 | 16.2 | 14.6 | 12.9 | 11.8 |
| 28 | 51.0 | 48.3 | 44.5 | 41.3 | 37.9 | 32.6 | 27.3 | 22.7 | 18.9 | 16.9 | 15.3 | 13.6 | 12.5 |
| 29 | 52.3 | 49.6 | 45.7 | 42.6 | 39.1 | 33.7 | 28.3 | 23.6 | 19.8 | 17.7 | 16.0 | 14.3 | 13.1 |
| 30 | 53.7 | 50.9 | 47.0 | 43.8 | 40.3 | 34.8 | 29.3 | 24.5 | 20.6 | 18.5 | 16.8 | 15.0 | 13.8 |
| 40 | 66.8 | 63.7 | 59.3 | 55.8 | 51.8 | 45.6 | 39.3 | 33.7 | 29.1 | 26.5 | 24.4 | 22.2 | 20.7 |
| 50 | 79.5 | 76.2 | 71.4 | 67.5 | 63.2 | 56.3 | 49.3 | 42.9 | 37.7 | 34.8 | 32.4 | 29.7 | 28.0 |
| 60 | 92.0 | 88.4 | 83.3 | 79.1 | 74.4 | 67.0 | 59.3 | 52.3 | 46.5 | 43.2 | 40.5 | 37.5 | 35.5 |
| 70 | 104.2 | 100.4 | 95.0 | 90.5 | 85.5 | 77.6 | 69.3 | 61.7 | 55.3 | 51.7 | 48.8 | 45.4 | 43.3 |
| 80 | 116.3 | 112.3 | 106.6 | 101.9 | 96.6 | 88.1 | 79.3 | 71.1 | 64.3 | 60.4 | 57.2 | 53.5 | 51.2 |
| 90 | 128.3 | 124.1 | 118.1 | 113.1 | 107.6 | 98.6 | 89.3 | 80.6 | 73.3 | 69.1 | 65.6 | 61.8 | 59.2 |
| 100 | 140.2 | 135.8 | 129.6 | 124.3 | 118.5 | 109.1 | 99.3 | 90.1 | 82.4 | 77.9 | 74.2 | 70.1 | 67.3 |

*Source:* Catherine M. Thompson, *Table of percentage points of the $\chi^2$ distribution*, Biometrika, Vol 32 (1941), by permission of the author and publisher.

Chart 3 for question no 8(a)

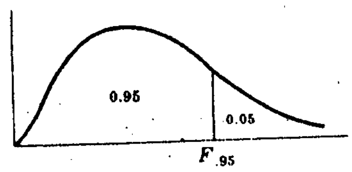


Md [illegible]

~~Appendix V~~

## 95th Percentile Values for the *F* Distribution

($\nu_1$ degrees of freedom in numerator)
($\nu_2$ degrees of freedom in denominator)




| $\nu_2$ \ $\nu_1$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 15 | 20 | 24 | 30 | 40 | 60 | 120 | ∞ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 161 | 200 | 216 | 225 | 230 | 234 | 237 | 239 | 241 | 242 | 244 | 246 | 248 | 249 | 250 | 251 | 252 | 253 | 254 |
| 2 | 18.5 | 19.0 | 19.2 | 19.2 | 19.3 | 19.3 | 19.4 | 19.4 | 19.4 | 19.4 | 19.4 | 19.4 | 19.4 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 |
| 3 | 10.1 | 9.55 | 9.28 | 9.12 | 9.01 | 8.94 | 8.89 | 8.85 | 8.81 | 8.79 | 8.74 | 8.70 | 8.66 | 8.64 | 8.62 | 8.59 | 8.57 | 8.55 | 8.53 |
| 4 | 7.71 | 6.94 | 6.59 | 6.39 | 6.26 | 6.16 | 6.09 | 6.04 | 6.00 | 5.96 | 5.91 | 5.86 | 5.80 | 5.77 | 5.75 | 5.72 | 5.69 | 5.66 | 5.63 |
| 5 | 6.61 | 5.79 | 5.41 | 5.19 | 5.05 | 4.95 | 4.88 | 4.82 | 4.77 | 4.74 | 4.68 | 4.62 | 4.56 | 4.53 | 4.50 | 4.46 | 4.43 | 4.40 | 4.37 |
| 6 | 5.99 | 5.14 | 4.76 | 4.53 | 4.39 | 4.28 | 4.21 | 4.15 | 4.10 | 4.06 | 4.00 | 3.94 | 3.87 | 3.84 | 3.81 | 3.77 | 3.74 | 3.70 | 3.67 |
| 7 | 5.59 | 4.74 | 4.35 | 4.12 | 3.97 | 3.87 | 3.79 | 3.73 | 3.68 | 3.64 | 3.57 | 3.51 | 3.44 | 3.41 | 3.38 | 3.34 | 3.30 | 3.27 | 3.23 |
| 8 | 5.32 | 4.46 | 4.07 | 3.84 | 3.69 | 3.58 | 3.50 | 3.44 | 3.39 | 3.35 | 3.28 | 3.22 | 3.15 | 3.12 | 3.08 | 3.04 | 3.01 | 2.97 | 2.93 |
| 9 | 5.12 | 4.26 | 3.86 | 3.63 | 3.48 | 3.37 | 3.29 | 3.23 | 3.18 | 3.14 | 3.07 | 3.01 | 2.94 | 2.90 | 2.86 | 2.83 | 2.79 | 2.75 | 2.71 |
| 10 | 4.96 | 4.10 | 3.71 | 3.48 | 3.33 | 3.22 | 3.14 | 3.07 | 3.02 | 2.98 | 2.91 | 2.85 | 2.77 | 2.74 | 2.70 | 2.66 | 2.62 | 2.58 | 2.54 |
| 11 | 4.84 | 3.98 | 3.59 | 3.36 | 3.20 | 3.09 | 3.01 | 2.95 | 2.90 | 2.85 | 2.79 | 2.72 | 2.65 | 2.61 | 2.57 | 2.53 | 2.49 | 2.45 | 2.40 |
| 12 | 4.75 | 3.89 | 3.49 | 3.26 | 3.11 | 3.00 | 2.91 | 2.85 | 2.80 | 2.75 | 2.69 | 2.62 | 2.54 | 2.51 | 2.47 | 2.43 | 2.38 | 2.34 | 2.30 |
| 13 | 4.67 | 3.81 | 3.41 | 3.18 | 3.03 | 2.92 | 2.83 | 2.77 | 2.71 | 2.67 | 2.60 | 2.53 | 2.46 | 2.42 | 2.38 | 2.34 | 2.30 | 2.25 | 2.21 |
| 14 | 4.60 | 3.74 | 3.34 | 3.11 | 2.96 | 2.85 | 2.76 | 2.70 | 2.65 | 2.60 | 2.53 | 2.46 | 2.39 | 2.35 | 2.31 | 2.27 | 2.22 | 2.18 | 2.13 |
| 15 | 4.54 | 3.68 | 3.29 | 3.06 | 2.90 | 2.79 | 2.71 | 2.64 | 2.59 | 2.54 | 2.48 | 2.40 | 2.33 | 2.29 | 2.25 | 2.20 | 2.16 | 2.11 | 2.07 |
| 16 | 4.49 | 3.63 | 3.24 | 3.01 | 2.85 | 2.74 | 2.66 | 2.59 | 2.54 | 2.49 | 2.42 | 2.35 | 2.28 | 2.24 | 2.19 | 2.15 | 2.11 | 2.06 | 2.01 |
| 17 | 4.45 | 3.59 | 3.20 | 2.96 | 2.81 | 2.70 | 2.61 | 2.55 | 2.49 | 2.45 | 2.38 | 2.31 | 2.23 | 2.19 | 2.15 | 2.10 | 2.06 | 2.01 | 1.96 |
| 18 | 4.41 | 3.55 | 3.16 | 2.93 | 2.77 | 2.66 | 2.58 | 2.51 | 2.46 | 2.41 | 2.34 | 2.27 | 2.19 | 2.15 | 2.11 | 2.06 | 2.02 | 1.97 | 1.92 |
| 19 | 4.38 | 3.52 | 3.13 | 2.90 | 2.74 | 2.63 | 2.54 | 2.48 | 2.42 | 2.38 | 2.31 | 2.23 | 2.16 | 2.11 | 2.07 | 2.03 | 1.98 | 1.93 | 1.88 |
| 20 | 4.35 | 3.49 | 3.10 | 2.87 | 2.71 | 2.60 | 2.51 | 2.45 | 2.39 | 2.35 | 2.28 | 2.20 | 2.12 | 2.08 | 2.04 | 1.99 | 1.95 | 1.90 | 1.84 |
| 21 | 4.32 | 3.47 | 3.07 | 2.84 | 2.68 | 2.57 | 2.49 | 2.42 | 2.37 | 2.32 | 2.25 | 2.18 | 2.10 | 2.05 | 2.01 | 1.96 | 1.92 | 1.87 | 1.81 |
| 22 | 4.30 | 3.44 | 3.05 | 2.82 | 2.66 | 2.55 | 2.46 | 2.40 | 2.34 | 2.30 | 2.23 | 2.15 | 2.07 | 2.03 | 1.98 | 1.94 | 1.89 | 1.84 | 1.78 |
| 23 | 4.28 | 3.42 | 3.03 | 2.80 | 2.64 | 2.53 | 2.44 | 2.37 | 2.32 | 2.27 | 2.20 | 2.13 | 2.05 | 2.01 | 1.96 | 1.91 | 1.86 | 1.81 | 1.76 |
| 24 | 4.26 | 3.40 | 3.01 | 2.78 | 2.62 | 2.51 | 2.42 | 2.36 | 2.30 | 2.25 | 2.18 | 2.11 | 2.03 | 1.98 | 1.94 | 1.89 | 1.84 | 1.79 | 1.73 |
| 25 | 4.24 | 3.39 | 2.99 | 2.76 | 2.60 | 2.49 | 2.40 | 2.34 | 2.28 | 2.24 | 2.16 | 2.09 | 2.01 | 1.96 | 1.92 | 1.87 | 1.82 | 1.77 | 1.71 |
| 26 | 4.23 | 3.37 | 2.98 | 2.74 | 2.59 | 2.47 | 2.39 | 2.32 | 2.27 | 2.22 | 2.15 | 2.07 | 1.99 | 1.95 | 1.90 | 1.85 | 1.80 | 1.75 | 1.69 |
| 27 | 4.21 | 3.35 | 2.96 | 2.73 | 2.57 | 2.46 | 2.37 | 2.31 | 2.25 | 2.20 | 2.13 | 2.06 | 1.97 | 1.93 | 1.88 | 1.84 | 1.79 | 1.73 | 1.67 |
| 28 | 4.20 | 3.34 | 2.95 | 2.71 | 2.56 | 2.45 | 2.36 | 2.29 | 2.24 | 2.19 | 2.12 | 2.04 | 1.96 | 1.91 | 1.87 | 1.82 | 1.77 | 1.71 | 1.65 |
| 29 | 4.18 | 3.33 | 2.93 | 2.70 | 2.55 | 2.43 | 2.35 | 2.28 | 2.22 | 2.18 | 2.10 | 2.03 | 1.94 | 1.90 | 1.85 | 1.81 | 1.75 | 1.70 | 1.64 |
| 30 | 4.17 | 3.32 | 2.92 | 2.69 | 2.53 | 2.42 | 2.33 | 2.27 | 2.21 | 2.16 | 2.09 | 2.01 | 1.93 | 1.89 | 1.84 | 1.79 | 1.74 | 1.68 | 1.62 |
| 40 | 4.08 | 3.23 | 2.84 | 2.61 | 2.45 | 2.34 | 2.25 | 2.18 | 2.12 | 2.08 | 2.00 | 1.92 | 1.84 | 1.79 | 1.74 | 1.69 | 1.64 | 1.58 | 1.51 |
| 60 | 4.00 | 3.15 | 2.76 | 2.53 | 2.37 | 2.25 | 2.17 | 2.10 | 2.04 | 1.99 | 1.92 | 1.84 | 1.75 | 1.70 | 1.65 | 1.59 | 1.53 | 1.47 | 1.39 |
| 120 | 3.92 | 3.07 | 2.68 | 2.45 | 2.29 | 2.18 | 2.09 | 2.02 | 1.96 | 1.91 | 1.83 | 1.75 | 1.66 | 1.61 | 1.55 | 1.50 | 1.43 | 1.35 | 1.25 |
| ∞ | 3.84 | 3.00 | 2.60 | 2.37 | 2.21 | 2.10 | 2.01 | 1.94 | 1.88 | 1.83 | 1.75 | 1.67 | 1.57 | 1.52 | 1.46 | 1.39 | 1.32 | 1.22 | 1.00 |

*Source:* E. S. Pearson and H. O. Hartley, *Biometrika Tables for Statisticians*, Vol. 2 (1972), Table 5, page 178, by permission.

Chart 4 for question no 8(b)

L-2/T-2/EEE Date : 01/01/2013

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-2 B. Sc. Engineering Examinations 2010-2011

Sub : **ME 267** (Mechanical Engineering Fundamentals)

Full Marks: 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

---

## SECTION – A

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

Steam tables and R 22 charts are attached.

1. (a) How does vapour compression (VC) refrigeration system differ from vapour absorption (VA) system? Draw a block diagram of LiBr-$H_2O$ VA system. **(8)**

   (b) The refrigerating effect of a refrigerator is 3TR (Tonne of Refrigeration). What does it mean? What is the refrigerating effect of that refrigerator in kW? **(5)**

   (c) Classify the refrigerant used in VC system with examples (write industrial name and chemical formula). **(5)**

   (d) Write a short note on AHU. **(5)**

   (e) A refrigerant R22 in VC system includes a liquid to suction heat exchanger. The heat exchanger warms saturated vapor coming from the evaporator from $-10^\circ$C to $5^\circ$C with liquids which comes from the condenser at $30^\circ$C. Calculate (i) COP of the system with heat exchanger, (ii) refrigerating capacity of the system with the heat exchanger, if compressor capacity is 12 L/s measured at the compressor suction. **(12)**

2. (a) Explain the different methods used to increase the efficiency of ideal Rankine cycle. **(15)**

   (b) Consider a steam power plant operating on ideal regenerative Rankine cycle with one open feed water heater. Steam enters the turbine at 15 MPa and $600^\circ$C and is condensed in the condenser at a pressure of 10 kPa. Some steam leaves turbine at a pressure of 1.2 MPa and enters the open feed water heater. Draw schematic and T-s diagram of the cycle. Determine the fraction of steam extracted from the turbine and the thermal efficiency of the cycle. **(17)**

   (c) Define the term 'Specific Steam Consumption'. **(3)**

3. (a) Draw a schematic of piston cylinder arrangement of a four stroke diesel engine and label it. **(5)**

   (b) How does thermal efficiency of diesel cycle change with compression ratio and cut-off ratio? 'For the same compression ratio, thermal efficiency of Otto cycle is higher than that of Diesel cycle' — Justify the statement. **(10)**

   (c) Write down the name and function of different sub-system used in an automotive engine. **(8)**

Contd .......... P/2

**ME 267**

**Contd. Q. No. 3**

(d) The compression ratio of an air-standard Otto cycle is 9.5. Prior to the isentropic compression process, the air is at 100 kPa, 35°C and 600 $cm^3$. The temperature at the end of isentropic expansion process is 800 K. Using specific heat values at room temperature; determine (i) the highest temperature and pressure in the cycle; (ii) the amount of heat transferred in heat addition process, in kJ; (iii) the thermal efficiency; and (iv) the mean effective pressure. **(12)**

4. (a) Deduce an expression for pressure ratio across the compressor of an ideal Brayton cycle for the maximum net work output per unit of mass flow if the state at the compressor inlet and the temperature at the turbine inlet are fixed. Use a cold air standard analysis. **(13)**

(b) Write the assumptions used in air-standard cycles. When is it called as cold-air standard assumption? **(6)**

(c) A gas turbine power plant operating on an ideal Brayton cycle has a pressure ratio of 8. The gas temperature is 300 K at the compressor inlet and 1300 K at the turbine inlet. If the compressor efficiency and turbine efficiency are 80% and 85% respectively, determine (i) the back work ratio, (ii) the thermal efficiency and (iii) the turbine exit temperature of the cycle. **(14)**

(d) What is meant by the term cogeneration? **(2)**

## SECTION – B

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

Make reasonable assumptions in case of any missing data.

5. (a) What is a quasi-equilibrium process? What is its importance in engineering? **(7)**

(b) Air at normal temperature and pressure contained in a closed tank adheres to the continuum hypothesis. Yet when sufficient air has been drawn from the tank, the hypothesis no longer applies to the remaining air. Why? Hence, write down the differences between the classical and statistical approaches to thermodynamics? **(9)**

(c) Sketch (neatly) the common p-T diagram for water and label, **(7)**

(i) The critical state

(ii) The triple point

(iii) The solid, liquid, and vapor regions

(iv) Indicate the correct slope of the fusion (melting) line (i.e., either a positive or negative slope)

Contd .......... P/3

**ME 267**

**Contd. Q. No. 5**

(d) Steam enters a converging-diverging nozzle operating at steady state with $P_1$ = 4 MPa, $T_1$ = 400°C, and a velocity of 10 m/s. The steam flows through the nozzle with negligible heat transfer and no significant change in potential energy. At the exit, $P_2$ = 1.5 MPa, and the velocity is 665 m/s. The mass flow rate is 2 kg/s. Determine the exit area of the nozzle. **(10)**

(e) A system undergoes a process between two fixed states first in a reversible manner and then in an irreversible manner. For which case is the entropy change greater? Why? **(2)**

6. (a) Derive the Bernoulli equation using the first law of thermodynamics for a steady, incompressible, inviscid flow. Hence, state the conditions under which the first law of thermodynamics reduces to the Bernoulli equation. **(15)**

(b) What are the primary differences between fans, blowers, and compressors? Discuss in terms of pressure rise. **(3)**

(c) Explain with neat sketch the working principle of a Pelton wheel. **(11)**

(d) Discuss the primary differences between a positive displacement pump and a rotodynamic pump. **(6)**

7. (a) Define reversible and irreversible process. Write down the names of the factors that cause a process to be irreversible. **(7)**

(b) Define mechanical energy. Write down at least one transitional and one stored form of the following energy categories: **(5)**

 (i) Mechanical energy
 (ii) Electrical energy
 (iii) Thermal energy

(c) Write short note on the following topics: **(10)**

 (i) Nuclear fuels
 (ii) Photovoltaic cell

(d) Draw the equivalent thermal circuits for the composite wall for case (i) surfaces normal to the x-direction are isothermal, case (ii) surfaces parallel to the x-direction are adiabatic. Assume one-dimensional conditions. **(13)**

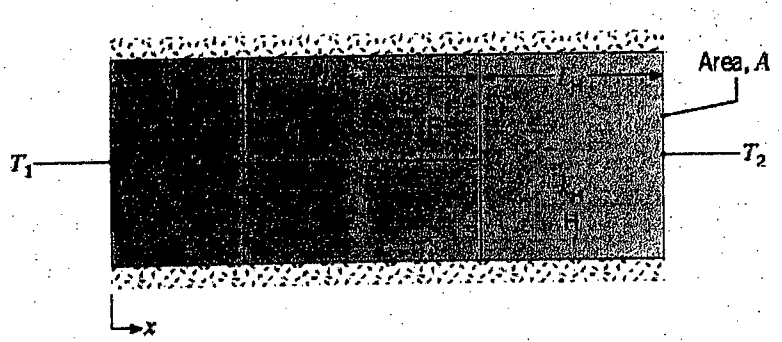



Figure for Q. 7~~(e)~~d

Contd .......... P/4

**ME 267**

8. (a) Discuss the important factors that should be considered while designing a boiler. **(8)**

(b) Draw the schematic diagram of a boiler setup showing the relative position of different boiler accessories. **(7)**

(c) Discuss the major sources of energy loss in a boiler. **(6)**

(d) Compare fire tube and water tube boilers. **(8)**

(e) Define entropy. An inventor claims to have developed a machine which might be used as the source of power for driving a ship. He supplies you the following design (as shown in Fig. 8(e)). **(1+5=6)**

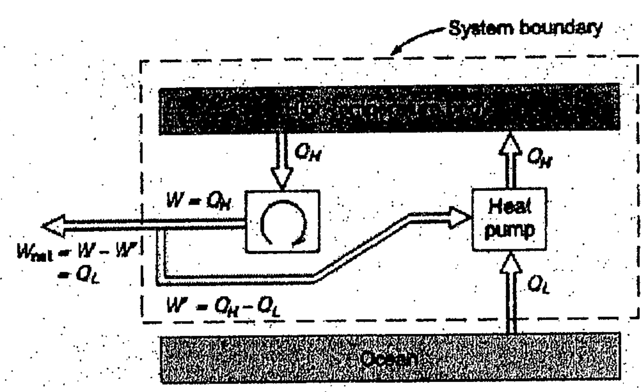



Figure for Q. 8(e)

Will you accept his design? Discuss it from the thermodynamic point of view.

-----------------------------------

$H_2O$

Saturated water—Pressure table

| Press., P kPa | Sat. temp., $T_{sat}$ °C | Specific volume, m³/kg: Sat. liquid, $v_f$ | Sat. vapor, $v_g$ | Internal energy, kJ/kg: Sat. liquid, $u_f$ | Evap., $u_{fg}$ | Sat. vapor, $u_g$ | Enthalpy, kJ/kg: Sat. liquid, $h_f$ | Evap., $h_{fg}$ | Sat. vapor, $h_g$ | Entropy, kJ/kg · K: Sat. liquid, $s_f$ | Evap., $s_{fg}$ | Sat. vapor, $s_g$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.6113 | 0.01 | 0.001000 | 206.14 | 0.00 | 2375.3 | 2375.3 | 0.01 | 2501.3 | 2501.4 | 0.0000 | 9.1562 | 9.1562 |
| 1.0 | 6.98 | 0.001000 | 129.21 | 29,30 | 2355.7 | 2385.0 | 29.30 | 2484.9 | 2514.2 | 0.1059 | 8.8697 | 8.9756 |
| 1.5 | 13.03 | 0.001001 | 87.98 | 54.71 | 2338.6 | 2393.3 | 54.71 | 2470.6 | 2525.3 | 0.1957 | 8.6322 | 8.8279 |
| 2.0 | 17.50 | 0.001001 | 67.00 | 73.48 | 2326.0 | 2399.5 | 73.48 | 2460.0 | 2533.5 | 0.2607 | 8.4629 | 8.7237 |
| 2.5 | 21.08 | 0.001002 | 54.25 | 88.48 | 2315.9 | 2404.4 | 88.49 | 2451.6 | 2540.0 | 0.3120 | 8.3311 | 8.6432 |
| 3.0 | 24.08 | 0.001003 | 45.67 | 101.04 | 2307.5 | 2408.5 | 101.05 | 2444.5 | 2545.5 | 0.3545 | 8.2231 | 8.5776 |
| 4.0 | 28.96 | 0.001004 | 34.80 | 121.45 | 2293.7 | 2415.2 | 121.46 | 2432.9 | 2554.4 | 0.4226 | 8.0520 | 8.4746 |
| 5.0 | 32.88 | 0.001005 | 28.19 | 137.81 | 2282.7 | 2420.5 | 137.82 | 2423.7 | 2561.5 | 0.4764 | 7.9187 | 8.3951 |
| 7.5 | 40.29 | 0.001008 | 19.24 | 168.78 | 2261.7 | 2430.5 | 168.79 | 2406.0 | 2574.8 | 0.5764 | 7.6750 | 8.2515 |
| 10 | 45.81 | 0.001010 | 14.67 | 191.82 | 2246.1 | 2437.9 | 191.83 | 2392.8 | 2584.7 | 0.6493 | 7.5009 | 8.1502 |
| 15 | 53.97 | 0.001014 | 10.02 | 225.92 | 2222.8 | 2448.7 | 225.94 | 2373.1 | 2599.1 | 0.7549 | 7.2536 | 8.0085 |
| 20 | 60.06 | 0.001017 | 7.649 | 251.38 | 2205.4 | 2456.7 | 251.40 | 2358.3 | 2609.7 | 0.8320 | 7.0766 | 7.9085 |
| 25 | 64.97 | 0.001020 | 6.204 | 271.90 | 2191.2 | 2463.1 | 271.93 | 2346.3 | 2618.2 | 0.8931 | 6.9383 | 7.8314 |
| 30 | 69.10 | 0.001022 | 5.229 | 289.20 | 2179.2 | 2468.4 | 289.23 | 2336.1 | 2625.3 | 0.9439 | 6.8247 | 7.7686 |
| 40 | 75.87 | 0.001027 | 3.993 | 317.53 | 2159.5 | 2477.0 | 317.58 | 2319.2 | 2636.8 | 1.0259 | 6.6441 | 7.6700 |
| 50 | 81.33 | 0.001030 | 3.240 | 340.44 | 2143.4 | 2483.9 | 340.49 | 2305.4 | 2645.9 | 1.0910 | 6.5029 | 7.5939 |
| 75 | 91.78 | 0.001037 | 2.217 | 384.31 | 2112.4 | 2496.7 | 384.39 | 2278.6 | 2663.0 | 1.2130 | 6.2434 | 7.4564 |
| Press., MPa | | | | | | | | | | | | |
| 0.100 | 99.63 | 0.001043 | 1.6940 | 417.36 | 2088.7 | 2506.1 | 417.46 | 2258.0 | 2675.5 | 1.3026 | 6.0568 | 7.3594 |
| 0.125 | 105.99 | 0.001048 | 1.3749 | 444.19 | 2069.3 | 2513.5 | 444.32 | 2241.0 | 2685.4 | 1.3740 | 5.9104 | 7.2844 |
| 0.150 | 111.37 | 0.001053 | 1.1593 | 466.94 | 2052.7 | 2519.7 | 467.11 | 2226.5 | 2693.6 | 1.4336 | 5.7897 | 7.2233 |
| 0.175 | 116.06 | 0.001057 | 1.0036 | 486.80 | 2038.1 | 2524.9 | 486.99 | 2213.6 | 2700.6 | 1.4849 | 5.6868 | 7.1717 |
| 0.200 | 120.23 | 0.001061 | 0.8857 | 504.49 | 2025.0 | 2529.5 | 504.70 | 2201.9 | 2706.7 | 1.5301 | 5.5970 | 7.1271 |
| 0.225 | 124.00 | 0.001064 | 0.7933 | 520.47 | 2013.1 | 2533.6 | 520.72 | 2191.3 | 2712.1 | 1.5706 | 5.5173 | 7.0878 |
| 0.250 | 127.44 | 0.001067 | 0.7187 | 535.10 | 2002.1 | 2537.2 | 535.37 | 2181.5 | 2716.9 | 1.6072 | 5.4455 | 7.0527 |
| 0.275 | 130.60 | 0.001070 | 0.6573 | 548.59 | 1991.9 | 2540.5 | 548.89 | 2172.4 | 2721.3 | 1.6408 | 5.3801 | 7.0209 |
| 0.300 | 133.55 | 0.001073 | 0.6058 | 561.15 | 1982.4 | 2543.6 | 561.47 | 2163.8 | 2725.3 | 1.6718 | 5.3201 | 6.9919 |
| 0.325 | 136.30 | 0.001076 | 0.5620 | 572.90 | 1973.5 | 2546.4 | 573.25 | 2155.8 | 2729.0 | 1.7006 | 5.2646 | 6.9652 |
| 0.350 | 138.88 | 0.001079 | 0.5243 | 583.95 | 1965.0 | 2548.9 | 584.33 | 2148.1 | 2732.4 | 1.7275 | 5.2130 | 6.9405 |
| 0.375 | 141.32 | 0.001081 | 0.4914 | 594.40 | 1956.9 | 2551.3 | 594.81 | 2140.8 | 2735.6 | 1.7528 | 5.1647 | 6.9175 |
| 0.40 | 143.63 | 0.001084 | 0.4625 | 604.31 | 1949.3 | 2553.6 | 604.74 | 2133.8 | 2738.6 | 1.7766 | 5.1193 | 6.8959 |
| 0.45 | 147.93 | 0.001088 | 0.4140 | 622.77 | 1934.9 | 2557.6 | 623.25 | 2120.7 | 2743.9 | 1.8207 | 5.0359 | 6.8565 |
| 0.50 | 151.86 | 0.001093 | 0.3749 | 639.68 | 1921.6 | 2561.2 | 640.23 | 2108.5 | 2748.7 | 1.8607 | 4.9606 | 6.8213 |
| 0.55 | 155.48 | 0.001097 | 0.3427 | 655.32 | 1909.2 | 2564.5 | 665.93 | 2097.0 | 2753.0 | 1.8973 | 4.8920 | 6.7893 |
| 0.60 | 158.85 | 0.001101 | 0.3157 | 669.90 | 1897.5 | 2567.4 | 670.56 | 2086.3 | 2756.8 | 1.9312 | 4.8288 | 6.7600 |
| 0.65 | 162.01 | 0.001104 | 0.2927 | 683.56 | 1886.5 | 2570.1 | 684.28 | 2076.0 | 2760.3 | 1.9627 | 4.7703 | 6.7331 |
| 0.70 | 164.97 | 0.001108 | 0.2729 | 696.44 | 1876.1 | 2572.5 | 697.22 | 2066.3 | 2763.5 | 1.9922 | 4.7158 | 6.7080 |
| 0.75 | 167.78 | 0.001112 | 0.2556 | 708.64 | 1866.1 | 2574.7 | 709.47 | 2057.0 | 2766.4 | 2.0200 | 4.6647 | 6.6847 |
| 0.80 | 170.43 | 0.001115 | 0.2404 | 720.22 | 1856.6 | 2576.8 | 721.11 | 2048.0 | 2769.1 | 2.0462 | 4.6166 | 6.6628 |
| 0.85 | 172.96 | 0.001118 | 0.2270 | 731.27 | 1847.4 | 2578.7 | 732.22 | 2039.4 | 2771.6 | 2.0710 | 4.5711 | 6.6421 |
| 0.90 | 175.38 | 0.001121 | 0.2150 | 741.83 | 1838.6 | 2580.5 | 742.83 | 2031.1 | 2773.9 | 2.0946 | 4.5280 | 6.6226 |
| 0.95 | 177.69 | 0.001124 | 0.2042 | 751.95 | 1830.2 | 2582.1 | 753.02 | 2023.1 | 2776.1 | 2.1172 | 4.4869 | 6.6041 |
| 1.00 | 179.91 | 0.001127 | 0.19444 | 761.68 | 1822.0 | 2583.6 | 762.81 | 2015.3 | 2778.1 | 2.1387 | 4.4478 | 6.5865 |
| 1.10 | 184.09 | 0.001133 | 0.17753 | 780.09 | 1806.3 | 2586.4 | 781.34 | 2000.4 | 2871.7 | 2.1792 | 4.3744 | 6.5536 |
| [illegible] | 187.99 | 0.001139 | 0.16333 | 797.29 | 1791.5 | 2588.8 | 798.65 | 1986.2 | 2784.8 | 2.2166 | 4.3067 | 6.5233 |
| [illegible] | [illegible] | 0.001144 | 0.15125 | 813.44 | 1777.5 | 2591.0 | 814.93 | 1972.7 | 2787.6 | 2.2515 | 4.2438 | 6.4953 |

Superheated water (*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 | v m³/kg | u kJ/kg | h kJ/kg | s kJ/kg · K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P = 1.00 MPa (179.91°C) | | | | P = 1.20 MPa (187.99°C) | | | | P = 1.40 MPa (195.07°C) | | | |
| Sat. | 0.19444 | 2583.6 | 2778.1 | 6.5865 | 0.16333 | 2588.8 | 2784.8 | 6.5233 | 0.14084 | 2592.8 | 2790.0 | 6.4693 |
| 200 | 0.2060 | 2621.9 | 2827.9 | 6.6940 | 0.16930 | 2612.8 | 2815.9 | 6.5898 | 0.14302 | 2603.1 | 2803.3 | 6.4975 |
| 250 | 0.2327 | 2709.9 | 2942.6 | 6.9247 | 0.19234 | 2704.2 | 2935.0 | 6.8294 | 0.16350 | 2698.3 | 2927.2 | 6.7467 |
| 300 | 0.2579 | 2793.2 | 3051.2 | 7.1229 | 0.2138 | 2789.2 | 3045.8 | 7.0317 | 0.18228 | 2785.2 | 3040.4 | 6.9534 |
| 350 | 0.2825 | 2875.2 | 3157.7 | 7.3011 | 0.2345 | 2872.2 | 3153.6 | 7.2121 | 0.2003 | 2869.2 | 3149.5 | 7.1360 |
| 400 | 0.3066 | 2957.3 | 3263.9 | 7.4651 | 0.2548 | 2954.9 | 3260.7 | 7.3774 | 0.2178 | 2952.5 | 3257.5 | 7.3026 |
| 500 | 0.3541 | 3124.4 | 3478.5 | 7.7622 | 0.2946 | 3122.8 | 3476.3 | 7.6759 | 0.2521 | 3121.1 | 3474.1 | 7.6027 |
| 600 | 0.4011 | 3296.8 | 3697.9 | 8.0290 | 0.3339 | 3295.6 | 3696.3 | 7.9435 | 0.2860 | 3294.4 | 3694.8 | 7.8710 |
| 700 | 0.4478 | 3475.3 | 3923.1 | 8.2731 | 0.3729 | 3474.4 | 3922.0 | 8.1881 | 0.3195 | 3473.6 | 3920.8 | 8.1160 |
| 800 | 0.4943 | 3660.4 | 4154.7 | 8.4996 | 0.4118 | 3659.7 | 4153.8 | 8.4148 | 0.3528 | 3659.0 | 4153.0 | 8.3431 |
| 900 | 0.5407 | 3852.2 | 4392.9 | 8.7118 | 0.4505 | 3851.6 | 4392.2 | 8.6272 | 0.3861 | 3851.1 | 4391.5 | 8.5556 |
| 1000 | 0.5871 | 4050.5 | 4637.6 | 8.9119 | 0.4892 | 4050.0 | 4637.0 | 8.8274 | 0.4192 | 4049.5 | 4636.4 | 8.7559 |
| 1100 | 0.6335 | 4255.1 | 4888.6 | 9.1017 | 0.5278 | 4254.6 | 4888.0 | 9.0172 | 0.4524 | 4254.1 | 4887.5 | 8.9457 |
| 1200 | 0.6798 | 4465.6 | 5145.4 | 9.2822 | 0.5665 | 4465.1 | 5144.9 | 9.1977 | 0.4855 | 4464.7 | 5144.4 | 9.1262 |
| 1300 | 0.7261 | 4681.3 | 5407.4 | 9.4543 | 0.6051 | 4680.9 | 5407.0 | 9.3698 | 0.5186 | 4680.4 | 5406.5 | 9.2984 |
| | P = 1.60 MPa (201.41°C) | | | | P = 1.80 MPa (207.15°C) | | | | P = 2.00 MPa (212.42°C) | | | |
| Sat. | 0.12380 | 2596.0 | 2794.0 | 6.4218 | 0.11042 | 2598.4 | 2797.1 | 6.3794 | 0.09963 | 2600.3 | 2799.5 | 6.3409 |
| 225 | 0.13287 | 2644.7 | 2857.3 | 6.5518 | 0.11673 | 2636.6 | 2846.7 | 6.4808 | 0.10377 | 2628.3 | 2835.8 | 6.4147 |
| 250 | 0.14184 | 2692.3 | 2919.2 | 6.6732 | 0.12497 | 2686.0 | 2911.0 | 6.6066 | 0.11144 | 2679.6 | 2902.5 | 6.5453 |
| 300 | 0.15862 | 2781.1 | 3034.8 | 6.8844 | 0.14021 | 2776.9 | 3029.2 | 6.8226 | 0.12547 | 2772.6 | 3023.5 | 6.7664 |
| 350 | 0.17456 | 2866.1 | 3145.4 | 7.0694 | 0.15457 | 2863.0 | 3141.2 | 7.0100 | 0.13857 | 2859.8 | 3137.0 | 6.9563 |
| 400 | 0.19005 | 2950.1 | 3254.2 | 7.2374 | 0.16847 | 2947.7 | 3250.9 | 7.1794 | 0.15120 | 2945.2 | 3247.6 | 7.1271 |
| 500 | 0.2203 | 3119.5 | 3472.0 | 7.5390 | 0.19550 | 3117.9 | 3469.8 | 7.4825 | 0.17568 | 3116.2 | 3467.6 | 7.4317 |
| 600 | 0.2500 | 3293.3 | 3693.2 | 7.8080 | 0.2220 | 3292.1 | 3691.7 | 7.7523 | 0.19960 | 3290.9 | 3690.1 | 7.7024 |
| 700 | 0.2794 | 3472.7 | 3919.7 | 8.0535 | 0.2482 | 3471.8 | 3918.5 | 7.9983 | 0.2232 | 3470.9 | 3917.4 | 7.9487 |
| 800 | 0.3086 | 3658.3 | 4152.1 | 8.2808 | 0.2742 | 3657.6 | 4151.2 | 8.2258 | 0.2467 | 3657.0 | 4150.3 | 8.1765 |
| 900 | 0.3377 | 3850.5 | 4390.8 | 8.4935 | 0.3001 | 3849.9 | 4390.1 | 8.4386 | 0.2700 | 3849.3 | 4389.4 | 8.3895 |
| 1000 | 0.3668 | 4049.0 | 4635.8 | 8.6938 | 0.3260 | 4048.5 | 4635.2 | 8.6391 | 0.2933 | 4048.0 | 4634.6 | 8.5901 |
| 1100 | 0.3958 | 4253.7 | 4887.0 | 8.8837 | 0.3518 | 4253.2 | 4886.4 | 8.8290 | 0.3166 | 4252.7 | 4885.9 | 8.7800 |
| 1200 | 0.4248 | 4464.2 | 5143.9 | 9.0643 | 0.3776 | 4463.7 | 5143.4 | 9.0096 | 0.3398 | 4463.3 | 5142.9 | 8.9607 |
| 1300 | 0.4538 | 4679.9 | 5406.0 | 9.2364 | 0.4034 | 4679.5 | 5405.6 | 9.1818 | 0.3631 | 4679.0 | 5405.1 | 9.1329 |
| | P = 2.50 MPa (223.99°C) | | | | P = 3.00 MPa (233.90°C) | | | | P = 3.50 MPa (242.60°C) | | | |
| Sat. | 0.07998 | 2603.1 | 2803.1 | 6.2575 | 0.06668 | 2604.1 | 2804.2 | 6.1869 | 0.05707 | 2603.7 | 2803.4 | 6.1253 |
| 225 | 0.08027 | 2605.6 | 2806.3 | 6.2639 | | | | | | | | |
| 250 | 0.08700 | 2662.6 | 2880.1 | 6.4085 | 0.07058 | 2644.0 | 2855.8 | 6.2872 | 0.05872 | 2623.7 | 2829.2 | 6.1749 |
| 300 | 0.09890 | 2761.6 | 3008.8 | 6.6438 | 0.08114 | 2750.1 | 2993.5 | 6.5390 | 0.06842 | 2738.0 | 2977.5 | 6.4461 |
| 350 | 0.10976 | 2851.9 | 3126.3 | 6.8403 | 0.09053 | 2843.7 | 3115.3 | 6.7428 | 0.07678 | 2835.3 | 3104.0 | 6.6579 |
| 400 | 0.12010 | 2939.1 | 3239.3 | 7.0148 | 0.09936 | 2932.8 | 3230.9 | 6.9212 | 0.08453 | 2926.4 | 3222.3 | 6.8405 |
| 450 | 0.13014 | 3025.5 | 3350.8 | 7.1745 | 0.10787 | 3020.4 | 3344.0 | 7.0834 | 0.09196 | 3015.3 | 3337.2 | 7.0052 |
| 500 | 0.13993 | 3112.1 | 3462.1 | 7.3234 | 0.11619 | 3108.0 | 3456.5 | 7.2338 | 0.09918 | 3103.0 | 3450.9 | 7.1572 |
| 600 | 0.15930 | 3288.0 | 3686.3 | 7.5960 | 0.13243 | 3285.0 | 3682.3 | 7.5085 | 0.11324 | 3282.1 | 3678.4 | 7.4339 |
| 700 | 0.17832 | 3468.7 | 3914.5 | 7.8435 | 0.14838 | 3466.5 | 3911.7 | 7.7571 | 0.12699 | 3464.3 | 3908.8 | 7.6837 |
| 800 | 0.19716 | 3655.3 | 4148.2 | 8.0720 | 0.16414 | 3653.5 | 4145.9 | 7.9862 | 0.14056 | 3651.8 | 4143.7 | 7.9134 |
| 900 | 0.21590 | 3847.9 | 4387.6 | 8.2853 | 0.17980 | 3846.5 | 4385.9 | 8.1999 | 0.15402 | 3845.0 | 4384.1 | 8.1276 |
| 1000 | 0.2346 | 4046.7 | 4633.1 | 8.4861 | 0.19541 | 4045.4 | 4631.6 | 8.4009 | 0.16743 | 4044.1 | 4630.1 | 8.3288 |
| 1100 | 0.2532 | 4251.5 | 4884.6 | 8.6762 | 0.21098 | 4250.3 | 4883.3 | 8.5912 | 0.18080 | 4249.2 | 4881.9 | 8.5192 |
| 1200 | 0.2718 | 4462.1 | 5141.7 | 8.8569 | 0.22652 | 4460.9 | 5140.5 | 8.7720 | 0.19415 | 4459.8 | 5139.3 | 8.7000 |
| 1300 | 0.2905 | 4677.8 | 5404.0 | 9.0291 | 0.24206 | 4676.6 | 5402.8 | 8.9442 | 0.20749 | 4675.5 | 5401.7 | 8.8723 |

H₂O

Superheated water (*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 | v m³/kg | u kJ/kg | h kJ/kg | s kJ/kg·K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P = 4.0 MPa (250.40°C) | | | | P = 4.5 MPa (257.49°C) | | | | P = 5.0 MPa (263.99°C) | | | |
| Sat. | 0.04978 | 2602.3 | 2801.4 | 6.0701 | 0.04406 | 2600.1 | 2798.3 | 6.0198 | 0.03944 | 2597.1 | 2794.3 | 5.9734 |
| 275 | 0.05457 | 2667.9 | 2886.2 | 6.2285 | 0.04730 | 2650.3 | 2863.2 | 6.1401 | 0.04141 | 2631.3 | 2838.3 | 6.0544 |
| 300 | 0.05884 | 2725.3 | 2960.7 | 6.3615 | 0.05135 | 2712.0 | 2943.1 | 6.2828 | 0.04532 | 2698.0 | 2924.5 | 6.2084 |
| 350 | 0.06645 | 2826.7 | 3092.5 | 6.5821 | 0.05840 | 2817.8 | 3080.6 | 6.5131 | 0.05194 | 2808.7 | 3068.4 | 6.4493 |
| 400 | 0.07341 | 2919.9 | 3213.6 | 6.7690 | 0.06475 | 2913.3 | 3204.7 | 6.7047 | 0.05781 | 2906.6 | 3195.7 | 6.6459 |
| 450 | 0.08002 | 3010.2 | 3330.3 | 6.9363 | 0.07074 | 3005.0 | 3323.3 | 6.8746 | 0.06330 | 2999.7 | 3316.2 | 6.8186 |
| 500 | 0.08643 | 3099.5 | 3445.3 | 7.0901 | 0.07651 | 3095.3 | 3439.6 | 7.0301 | 0.06857 | 3091.0 | 3433.8 | 6.9759 |
| 600 | 0.09885 | 3279.1 | 3674.4 | 7.3688 | 0.08765 | 3276.0 | 3670.5 | 7.3110 | 0.07869 | 3273.0 | 3666.5 | 7.2589 |
| 700 | 0.11095 | 3462.1 | 3905.9 | 7.6198 | 0.09847 | 3459.9 | 3903.0 | 7.5631 | 0.08849 | 3457.6 | 3900.1 | 7.5122 |
| 800 | 0.12287 | 3650.0 | 4141.5 | 7.8502 | 0.10911 | 3648.3 | 4139.3 | 7.7942 | 0.09811 | 3646.6 | 4137.1 | 7.7440 |
| 900 | 0.13469 | 3843.6 | 4382.3 | 8.0647 | 0.11965 | 3842.2 | 4380.6 | 8.0091 | 0.10762 | 3840.7 | 4378.8 | 7.9593 |
| 1000 | 0.14645 | 4042.9 | 4628.7 | 8.2662 | 0.13013 | 4041.6 | 4627.2 | 8.2108 | 0.11707 | 4040.4 | 4625.7 | 8.1612 |
| 1100 | 0.15817 | 4248.0 | 4880.6 | 8.4567 | 0.14056 | 4246.8 | 4879.3 | 8.4015 | 0.12648 | 4245.6 | 4878.0 | 8.3520 |
| 1200 | 0.16987 | 4458.6 | 5138.1 | 8.6376 | 0.15098 | 4457.5 | 5136.9 | 8.5825 | 0.13587 | 4456.3 | 5135.7 | 8.5331 |
| 1300 | 0.18156 | 4674.3 | 5400.5 | 8.8100 | 0.16139 | 4673.1 | 5399.4 | 8.7549 | 0.14526 | 4672.0 | 5398.2 | 8.7055 |
| | P = 6.0 MPa (275.64°C) | | | | P = 7.0 MPa (285.88°C) | | | | P = 8.0 MPa (295.06°C) | | | |
| Sat. | 0.03244 | 2589.7 | 2784.3 | 5.8892 | 0.02737 | 2580.5 | 2772.1 | 5.8133 | 0.02352 | 2569.8 | 2758.0 | 5.7432 |
| 300 | 0.03616 | 2667.2 | 2884.2 | 6.0674 | 0.02947 | 2632.2 | 2838.4 | 5.9305 | 0.02426 | 2590.9 | 2785.0 | 5.7906 |
| 350 | 0.04223 | 2789.6 | 3043.0 | 6.3335 | 0.03524 | 2769.4 | 3016.0 | 6.2283 | 0.02995 | 2747.7 | 2987.3 | 6.1301 |
| 400 | 0.04739 | 2892.9 | 3177.2 | 6.5408 | 0.03993 | 2878.6 | 3158.1 | 6.4478 | 0.03432 | 2863.8 | 3138.3 | 6.3634 |
| 450 | 0.05214 | 2988.9 | 3301.8 | 6.7193 | 0.04416 | 2978.0 | 3287.1 | 6.6327 | 0.03817 | 2966.7 | 3272.0 | 6.5551 |
| 500 | 0.05665 | 3082.2 | 3422.2 | 6.8803 | 0.04814 | 3073.4 | 3410.3 | 6.7975 | 0.04175 | 3064.3 | 3398.3 | 6.7240 |
| 550 | 0.06101 | 3174.6 | 3540.6 | 7.0288 | 0.05195 | 3167.2 | 3530.9 | 6.9486 | 0.04516 | 3159.8 | 3521.0 | 6.8778 |
| 600 | 0.06525 | 3266.9 | 3658.4 | 7.1677 | 0.05565 | 3260.7 | 3650.3 | 7.0894 | 0.04845 | 3254.4 | 3642.0 | 7.0206 |
| 700 | 0.07352 | 3453.1 | 3894.2 | 7.4234 | 0.06283 | 3448.5 | 3888.3 | 7.3476 | 0.05481 | 3443.9 | 3882.4 | 7.2812 |
| 800 | 0.08160 | 3643.1 | 4132.7 | 7.6566 | 0.06981 | 3639.5 | 4128.2 | 7.5822 | 0.06097 | 3636.0 | 4123.8 | 7.5173 |
| 900 | 0.08958 | 3837.8 | 4375.3 | 7.8727 | 0.07669 | 3835.0 | 4371.8 | 7.7991 | 0.06702 | 3832.1 | 4368.3 | 7.7351 |
| 1000 | 0.09749 | 4037.8 | 4622.7 | 8.0751 | 0.08350 | 4035.3 | 4619.8 | 8.0020 | 0.07301 | 4032.8 | 4616.9 | 7.9384 |
| 1100 | 0.10536 | 4243.3 | 4875.4 | 8.2661 | 0.09027 | 4240.9 | 4872.8 | 8.1933 | 0.07896 | 4238.6 | 4870.3 | 8.1300 |
| 1200 | 0.11321 | 4454.0 | 5133.3 | 8.4474 | 0.09703 | 4451.7 | 5130.9 | 8.3747 | 0.08489 | 4449.5 | 5128.5 | 8.3115 |
| 1300 | 0.12106 | 4669.6 | 5396.0 | 8.6199 | 0.10377 | 4667.3 | 5393.7 | 8.5475 | 0.09080 | 4665.0 | 5391.5 | 8.4842 |
| | P = 9.0 MPa (303.40°C) | | | | P = 10.0 MPa (318351.06°C) | | | | P = 12.5 MPa (327.89°C) | | | |
| Sat. | 0.02048 | 2557.8 | 2742.1 | 5.6772 | 0.018026 | 2544.4 | 2724.7 | 5.6141 | 0.013495 | 2505.1 | 2673.8 | 5.4624 |
| 325 | 0.02327 | 2646.6 | 2856.0 | 5.8712 | 0.019861 | 2610.4 | 2809.1 | 5.7568 | | | | |
| 350 | 0.02580 | 2724.4 | 2956.6 | 6.0361 | 0.02242 | 2699.2 | 2923.4 | 5.9443 | 0.016126 | 2624.6 | 2826.2 | 5.7118 |
| 400 | 0.02993 | 2848.4 | 3117.8 | 6.2854 | 0.02641 | 2832.4 | 3096.5 | 6.2120 | 0.02000 | 2789.3 | 3039.3 | 6.0417 |
| 450 | 0.03350 | 2955.2 | 3256.6 | 6.4844 | 0.02975 | 2943.4 | 3240.9 | 6.4190 | 0.02299 | 2912.5 | 3199.8 | 6.2719 |
| 500 | 0.03677 | 3055.2 | 3386.1 | 6.6576 | 0.03279 | 3045.8 | 3373.7 | 6.5966 | 0.02560 | 3021.7 | 3341.8 | 6.4618 |
| 550 | 0.03987 | 3152.2 | 3511.0 | 6.8142 | 0.03564 | 3144.6 | 3500.9 | 6.7561 | 0.02801 | 3125.0 | 3475.2 | 6.6290 |
| 600 | 0.04285 | 3248.1 | 3633.7 | 6.9589 | 0.03837 | 3241.7 | 3625.3 | 6.9029 | 0.03029 | 3225.4 | 3604.0 | 6.7810 |
| 650 | 0.04574 | 3343.6 | 3755.3 | 7.0943 | 0.04101 | 3338.2 | 3748.2 | 7.0398 | 0.03248 | 3324.4 | 3730.4 | 6.9218 |
| 700 | 0.04857 | 3439.3 | 3876.5 | 7.2221 | 0.04358 | 3434.7 | 3870.5 | 7.1687 | 0.03460 | 3422.9 | 3855.3 | 7.0536 |
| 800 | 0.05409 | 3632.5 | 4119.3 | 7.4596 | 0.04859 | 3628.9 | 4114.8 | 7.4077 | 0.03869 | 3620.0 | 4103.6 | 7.2965 |
| 900 | 0.05950 | 3829.2 | 4364.8 | 7.6783 | 0.05349 | 3826.3 | 4361.2 | 7.6272 | 0.04267 | 3819.1 | 4352.5 | 7.5182 |
| 1000 | 0.06485 | 4030.3 | 4614.0 | 7.8821 | 0.05832 | 4027.8 | 4611.0 | 7.8315 | 0.04658 | 4021.6 | 4603.8 | 7.7237 |
| 1100 | 0.07016 | 4236.3 | 4867.7 | 8.0740 | 0.06312 | 4234.0 | 4865.1 | 8.0237 | 0.05045 | 4228.2 | 4858.8 | 7.9165 |
| 1200 | 0.07544 | 4447.2 | 5126.2 | 8.2556 | 0.06789 | 4444.9 | 5123.8 | 8.2055 | 0.05430 | 4439.3 | 5118.0 | 8.0937 |
| 1300 | 0.08072 | 4662.7 | 5389.2 | 8.4284 | 0.07265 | 4460.5 | 5387.0 | 8.3783 | 0.05813 | 4654.8 | 5381.4 | 8.2717 |



H₂O

Superheated water (*Concluded*)

| 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 | v m³/kg | u kJ/kg | h kJ/kg | s kJ/kg·K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P = 15.0 MPa (342.24°C) | | | | P = 17.5 MPa (354.75°C) | | | | P = 20.0 MPa (365.81°C) | | | |
| Sat. | 0.010337 | 2455.5 | 2610.5 | 5.3098 | 0.007920 | 2390.2 | 2528.8 | 5.1419 | 0.005834 | 2293.0 | 2409.7 | 4.9269 |
| 350 | 0.011470 | 2520.4 | 2692.4 | 5.4421 | | | | | | | | |
| 400 | 0.015649 | 2740.7 | 2975.5 | 5.8811 | 0.012447 | 2685.0 | 2902.9 | 5.7213 | 0.009942 | 2619.3 | 2818.1 | 5.5540 |
| 450 | 0.018445 | 2879.5 | 3156.2 | 6.1404 | 0.015174 | 2844.2 | 3109.7 | 6.0184 | 0.012695 | 2806.2 | 3060.1 | 5.9017 |
| 500 | 0.02080 | 2996.6 | 3308.6 | 6.3443 | 0.017358 | 2970.3 | 3274.1 | 6.2383 | 0.014768 | 2942.9 | 3238.2 | 6.1401 |
| 550 | 0.02293 | 3104.7 | 3448.6 | 6.5199 | 0.019288 | 3083.9 | 3421.4 | 6.4230 | 0.016555 | 3062.4 | 3393.5 | 6.3348 |
| 600 | 0.02491 | 3208.6 | 3582.3 | 6.6776 | 0.02106 | 3191.5 | 3560.1 | 6.5866 | 0.018178 | 3174.0 | 3537.6 | 6.5048 |
| 650 | 0.02680 | 3310.3 | 3712.3 | 6.8224 | 0.02274 | 3296.0 | 3693.9 | 6.7357 | 0.019693 | 3281.4 | 3675.3 | 6.6582 |
| 700 | 0.02861 | 3410.9 | 3840.1 | 6.9572 | 0.02434 | 3398.7 | 3824.6 | 6.8736 | 0.02113 | 3386.4 | 3809.0 | 6.7993 |
| 800 | 0.03210 | 3610.9 | 4092.4 | 7.2040 | 0.02738 | 3601.8 | 4081.1 | 7.1244 | 0.02385 | 3592.7 | 4069.7 | 7.0544 |
| 900 | 0.03546 | 3811.9 | 4343.8 | 7.4279 | 0.03031 | 3804.7 | 4335.1 | 7.3507 | 0.02645 | 3797.5 | 4326.4 | 7.2830 |
| 1000 | 0.03875 | 4015.4 | 4596.6 | 7.6348 | 0.03316 | 4009.3 | 4589.5 | 7.5589 | 0.02897 | 4003.1 | 4582.5 | 7.4925 |
| 1100 | 0.04200 | 4222.6 | 4852.6 | 7.8283 | 0.03597 | 4216.9 | 4846.4 | 7.7531 | 0.03145 | 4211.3 | 4840.2 | 7.6874 |
| 1200 | 0.04523 | 4433.8 | 5112.3 | 8.0108 | 0.03876 | 4428.3 | 5106.6 | 7.9360 | 0.03391 | 4422.8 | 5101.0 | 7.8707 |
| 1300 | 0.04845 | 4649.1 | 5376.0 | 8.1840 | 0.04154 | 4643.5 | 5370.5 | 8.1093 | 0.03636 | 4638.0 | 5365.1 | 8.0442 |
| | P = 25.0 MPa | | | | P = 30.0 MPa | | | | P = 35.0 MPa | | | |
| 375 | 0.0019731 | 1798.7 | 1848.0 | 4.0320 | 0.0017892 | 1737.8 | 1791.5 | 3.9305 | 0.0017003 | 1702.9 | 1762.4 | 3.8722 |
| 400 | 0.006004 | 2430.1 | 2580.2 | 5.1418 | 0.002790 | 2067.4 | 2151.1 | 4.4728 | 0.002100 | 1914.1 | 1987.6 | 4.2126 |
| 425 | 0.007881 | 2609.2 | 2806.3 | 5.4723 | 0.005303 | 2455.1 | 2614.2 | 5.1504 | 0.003428 | 2253.4 | 2373.4 | 4.7747 |
| 450 | 0.009162 | 2720.7 | 2949.7 | 5.6744 | 0.006735 | 2619.3 | 2821.4 | 5.4424 | 0.004961 | 2498.7 | 2672.4 | 5.1962 |
| 500 | 0.011123 | 2884.3 | 3162.4 | 5.9592 | 0.008678 | 2820.7 | 3081.1 | 5.7905 | 0.006927 | 2751.9 | 2994.4 | 5.6282 |
| 550 | 0.012724 | 3017.5 | 3335.6 | 6.1765 | 0.010168 | 2970.3 | 3275.4 | 6.0342 | 0.008345 | 2921.0 | 3213.0 | 5.9026 |
| 600 | 0.014137 | 3137.9 | 3491.4 | 6.3602 | 0.011446 | 3100.5 | 3443.9 | 6.2331 | 0.009527 | 3062.0 | 3395.5 | 6.1179 |
| 650 | 0.015433 | 3251.6 | 3637.4 | 6.5229 | 0.012596 | 3221.0 | 3598.9 | 6.4058 | 0.010575 | 3189.8 | 3559.9 | 6.3010 |
| 700 | 0.016646 | 3361.3 | 3777.5 | 6.6707 | 0.013661 | 3335.8 | 3745.6 | 6.5606 | 0.011533 | 3309.8 | 3713.5 | 6.4631 |
| 800 | 0.018912 | 3574.3 | 4047.1 | 6.9345 | 0.015623 | 3555.5 | 4024.2 | 6.8332 | 0.013278 | 3536.7 | 4001.5 | 6.7450 |
| 900 | 0.021045 | 3783.0 | 4309.1 | 7.1680 | 0.017448 | 3768.5 | 4291.9 | 7.0718 | 0.014883 | 3754.0 | 4274.9 | 6.9386 |
| 1000 | 0.02310 | 3990.9 | 4568.5 | 7.3802 | 0.019196 | 3978.8 | 4554.7 | 7.2867 | 0.016410 | 3966.7 | 4541.1 | 7.2064 |
| 1100 | 0.02512 | 4200.2 | 4828.2 | 7.5765 | 0.020903 | 4189.2 | 4816.3 | 7.4845 | 0.017895 | 4178.3 | 4804.6 | 7.4037 |
| 1200 | 0.02711 | 4412.0 | 5089.9 | 7.7605 | 0.022589 | 4401.3 | 5079.0 | 7.6692 | 0.019360 | 4390.7 | 5068.3 | 7.5910 |
| 1300 | 0.02910 | 4626.9 | 5354.4 | 7.9342 | 0.024266 | 4616.0 | 5344.0 | 7.8432 | 0.020815 | 4605.1 | 5333.6 | 7.7653 |
| | P = 40.0 MPa | | | | P = 50.0 MPa | | | | P = 60.0 MPa | | | |
| 375 | 0.0016407 | 1677.1 | 1742.8 | 3.8290 | 0.0015594 | 1638.6 | 1716.6 | 3.7639 | 0.0015028 | 1609.4 | 1699.5 | 3.7141 |
| 400 | 0.0019077 | 1854.6 | 1930.9 | 4.1135 | 0.0017309 | 1788.1 | 1874.6 | 4.0031 | 0.0016335 | 1745.4 | 1843.4 | 3.9318 |
| 425 | 0.002532 | 2096.9 | 2198.1 | 4.5029 | 0.002007 | 1959.7 | 2060.0 | 4.2734 | 0.0018165 | 1892.7 | 2001.7 | 4.1626 |
| 450 | 0.003693 | 2365.1 | 2512.8 | 4.9459 | 0.002486 | 2159.6 | 2284.0 | 4.5884 | 0.002085 | 2053.9 | 2179.0 | 4.4121 |
| 500 | 0.005622 | 2678.4 | 2903.3 | 5.4700 | 0.003892 | 2525.5 | 2720.1 | 5.1726 | 0.002956 | 2390.6 | 2567.9 | 4.9321 |
| 550 | 0.006984 | 2869.7 | 3149.1 | 5.7785 | 0.005118 | 2763.6 | 3019.5 | 5.5485 | 0.003956 | 2658.8 | 2896.2 | 5.3441 |
| 600 | 0.008094 | 3022.6 | 3346.4 | 6.0144 | 0.006112 | 2942.0 | 3247.6 | 5.8178 | 0.004834 | 2861.1 | 3151.2 | 5.6452 |
| 650 | 0.009063 | 3158.0 | 3520.6 | 6.2054 | 0.006966 | 3093.5 | 3441.8 | 6.0342 | 0.005595 | 3028.8 | 3364.5 | 5.8829 |
| 700 | 0.009941 | 3283.6 | 3681.2 | 6.3750 | 0.007727 | 3230.5 | 3616.8 | 6.2189 | 0.006272 | 3177.2 | 3553.5 | 6.0824 |
| 800 | 0.011523 | 3517.8 | 3978.7 | 6.6662 | 0.009076 | 3479.8 | 3933.6 | 6.5290 | 0.007459 | 3441.5 | 3889.1 | 6.4109 |
| 900 | 0.012962 | 3739.4 | 4257.9 | 6.9150 | 0.010283 | 3710.3 | 4224.4 | 6.7882 | 0.008508 | 3681.0 | 4191.5 | 6.6805 |
| 1000 | 0.014324 | 3954.6 | 4527.6 | 7.1356 | 0.011411 | 3930.5 | 4501.1 | 7.0146 | 0.009480 | 3906.4 | 4475.2 | 6.9127 |
| 1100 | 0.015642 | 4167.4 | 4793.1 | 7.3364 | 0.012496 | 4145.7 | 4770.5 | 7.2184 | 0.010409 | 4124.1 | 4748.6 | 7.1195 |
| 1200 | 0.016940 | 4380.1 | 5057.7 | 7.5224 | 0.013561 | 4359.1 | 5037.2 | 7.4058 | 0.011317 | 4338.2 | 5017.2 | 7.3083 |
| 1300 | 0.018229 | 4594.3 | 5323.5 | 7.6969 | 0.014616 | 4572.8 | 5303.6 | 7.5808 | 0.012215 | 4551.4 | 5284.3 | 7.4837 |

Ideal-gas properties of air

| T K | h kJ/kg | $P_r$ | u kJ/kg | $v_r$ | $s^\circ$ kJ/kg · K |
|---|---|---|---|---|---|
| 200 | 199.97 | 0.3363 | 142.56 | 1707.0 | 1.29559 |
| 210 | 209.97 | 0.3987 | 149.69 | 1512.0 | 1.34444 |
| 220 | 219.97 | 0.4690 | 156.82 | 1346.0 | 1.39105 |
| 230 | 230.02 | 0.5477 | 164.00 | 1205.0 | 1.43557 |
| 240 | 240.02 | 0.6355 | 171.13 | 1084.0 | 1.47824 |
| 250 | 250.05 | 0.7329 | 178.28 | 979.0 | 1.51917 |
| 260 | 260.09 | 0.8405 | 185.45 | 887.8 | 1.55848 |
| 270 | 270.11 | 0.9590 | 192.60 | 808.0 | 1.59634 |
| 280 | 280.13 | 1.0889 | 199.75 | 738.0 | 1.63279 |
| 285 | 285.14 | 1.1584 | 203.33 | 706.1 | 1.65055 |
| 290 | 290.16 | 1.2311 | 206.91 | 676.1 | 1.66802 |
| 295 | 295.17 | 1.3068 | 210.49 | 647.9 | 1.68515 |
| 300 | 300.19 | 1.3860 | 214.07 | 621.2 | 1.70203 |
| 305 | 305.22 | 1.4686 | 217.67 | 596.0 | 1.71865 |
| 310 | 310.24 | 1.5546 | 221.25 | 572.3 | 1.73498 |
| 315 | 315.27 | 1.6442 | 224.85 | 549.8 | 1.75106 |
| 320 | 320.29 | 1.7375 | 228.42 | 528.6 | 1.76690 |
| 325 | 325.31 | 1.8345 | 232.02 | 508.4 | 1.78249 |
| 330 | 330.34 | 1.9352 | 235.61 | 489.4 | 1.79783 |
| 340 | 340.42 | 2.149 | 242.82 | 454.1 | 1.82790 |
| 350 | 350.49 | 2.379 | 250.02 | 422.2 | 1.85708 |
| 360 | 360.58 | 2.626 | 257.24 | 393.4 | 1.88543 |
| 370 | 370.67 | 2.892 | 264.46 | 367.2 | 1.91313 |
| 380 | 380.77 | 3.176 | 271.69 | 343.4 | 1.94001 |
| 390 | 390.88 | 3.481 | 278.93 | 321.5 | 1.96633 |
| 400 | 400.98 | 3.806 | 286.16 | 301.6 | 1.99194 |
| 410 | 411.12 | 4.153 | 293.43 | 283.3 | 2.01699 |
| 420 | 421.26 | 4.522 | 300.69 | 266.6 | 2.04142 |
| 430 | 431.43 | 4.915 | 307.99 | 251.1 | 2.06533 |
| 440 | 441.61 | 5.332 | 315.30 | 236.8 | 2.08870 |
| 450 | 451.80 | 5.775 | 322.62 | 223.6 | 2.11161 |
| 460 | 462.02 | 6.245 | 329.97 | 211.4 | 2.13407 |
| 470 | 472.24 | 6.742 | 337.32 | 200.1 | 2.15604 |
| 480 | 482.49 | 7.268 | 344.70 | 189.5 | 2.17760 |
| 490 | 492.74 | 7.824 | 352.08 | 179.7 | 2.19876 |
| 500 | 503.02 | 8.411 | 359.49 | 170.6 | 2.21952 |
| 510 | 513.32 | 9.031 | 366.92 | 162.1 | 2.23993 |
| 520 | 523.63 | 9.684 | 374.36 | 154.1 | 2.25997 |
| 530 | 533.98 | 10.37 | 381.84 | 146.7 | 2.27967 |
| 540 | 544.35 | 11.10 | 389.34 | 139.7 | 2.29906 |
| 550 | 555.74 | 11.86 | 396.86 | 133.1 | 2.31809 |
| [illegible] | 565.17 | 12.66 | 404.42 | 127.0 | 2.33685 |
| [illegible] | [illegible] | 13.50 | 411.97 | 121.2 | 2.35531 |
| 580 | 586.04 | 14.38 | 419.55 | 115.7 | 2.37348 |
| 590 | 596.52 | 15.31 | 427.15 | 110.6 | 2.39140 |
| 600 | 607.02 | 16.28 | 434.78 | 105.8 | 2.40902 |
| 610 | 617.53 | 17.30 | 442.42 | 101.2 | 2.42644 |
| 620 | 628.07 | 18.36 | 450.09 | 96.92 | 2.44356 |
| 630 | 683.63 | 19.84 | 457.78 | 92.84 | 2.46048 |
| 640 | 649.22 | 20.64 | 465.50 | 88.99 | 2.47716 |
| 650 | 659.84 | 21.86 | 473.25 | 85.34 | 2.49364 |
| 660 | 670.47 | 23.13 | 481.01 | 81.89 | 2.50985 |
| 670 | 681.14 | 24.46 | 488.81 | 78.61 | 2.52589 |
| 680 | 691.82 | 25.85 | 496.62 | 75.50 | 2.54175 |
| 690 | 702.52 | 27.29 | 504.45 | 72.56 | 2.55731 |
| 700 | 713.27 | 28.80 | 512.33 | 69.76 | 2.57277 |
| 710 | 724.04 | 30.38 | 520.23 | 67.07 | 2.58810 |
| 720 | 734.82 | 32.02 | 528.14 | 64.53 | 2.60319 |
| 730 | 745.62 | 33.72 | 536.07 | 62.13 | 2.61803 |
| 740 | 756.44 | 35.50 | 544.02 | 59.82 | 2.63280 |
| 750 | 767.29 | 37.35 | 551.99 | 57.63 | 2.64737 |
| 760 | 778.18 | 39.27 | 560.01 | 55.54 | 2.66176 |
| 780 | 800.03 | 43.35 | 576.12 | 51.64 | 2.69013 |
| 800 | 821.95 | 47.75 | 592.30 | 48.08 | 2.71787 |
| 820 | 843.98 | 52.59 | 608.59 | 44.84 | 2.74504 |
| 840 | 866.08 | 57.60 | 624.95 | 41.85 | 2.77170 |
| 860 | 888.27 | 63.09 | 641.40 | 39.12 | 2.79783 |
| 880 | 910.56 | 68.98 | 657.95 | 36.61 | 2.82344 |
| 900 | 932.93 | 75.29 | 674.58 | 34.31 | 2.84856 |
| 920 | 955.38 | 82.05 | 691.28 | 32.18 | 2.87324 |
| 940 | 977.92 | 89.28 | 708.08 | 30.22 | 2.89748 |
| 960 | 1000.55 | 97.00 | 725.02 | 28.40 | 2.92128 |
| 980 | 1023.25 | 105.2 | 741.98 | 26.73 | 2.94468 |
| 1000 | 1046.04 | 114.0 | 758.94 | 25.17 | 2.96770 |
| 1020 | 1068.89 | 123.4 | 776.10 | 23.72 | 2.99034 |
| 1040 | 1091.85 | 133.3 | 793.36 | 23.29 | 3.01260 |
| 1060 | 1114.86 | 143.9 | 810.62 | 21.14 | 3.03449 |
| 1080 | 1137.89 | 155.2 | 827.88 | 19.98 | 3.05608 |
| 1100 | 1161.07 | 167.1 | 845.33 | 18.896 | 3.07732 |
| 1120 | 1184.28 | 179.7 | 862.79 | 17.886 | 3.09825 |
| 1140 | 1207.57 | 193.1 | 880.35 | 16.946 | 3.11883 |
| 1160 | 1230.92 | 207.2 | 897.91 | 16.064 | 3.13916 |
| 1180 | 1254.34 | 222.2 | 915.57 | 15.241 | 3.15916 |
| 1200 | 1277.79 | 238.0 | 933.33 | 14.470 | 3.17888 |
| 1220 | 1301.31 | 254.7 | 951.09 | 13.747 | 3.19834 |
| 1240 | 1324.93 | 272.3 | 968.95 | 13.069 | 3.21751 |

Air

N2



Air

Ideal-gas properties of air (*Concluded*)

| T K | h kJ/kg | $P_r$ | u kJ/kg | $v_r$ | $s^\circ$ kJ/kg · K |
|---|---|---|---|---|---|
| 1260 | 1348.55 | 290.8 | 986.90 | 12.435 | 3.23638 |
| 1280 | 1372.24 | 310.4 | 1004.76 | 11.835 | 3.25510 |
| 1300 | 1395.97 | 330.9 | 1022.82 | 11.275 | 3.27345 |
| 1320 | 1419.76 | 352.5 | 1040.88 | 10.747 | 3.29160 |
| 1340 | 1443.60 | 375.3 | 1058.94 | 10.247 | 3.30959 |
| 1360 | 1467.49 | 399.1 | 1077.10 | 9.780 | 3.32724 |
| 1380 | 1491.44 | 424.2 | 1095.26 | 9.337 | 3.34474 |
| 1400 | 1515.42 | 450.5 | 1113.52 | 8.919 | 3.36200 |
| 1420 | 1539.44 | 478.0 | 1131.77 | 8.526 | 3.37901 |
| 1440 | 1563.51 | 506.9 | 1150.13 | 8.153 | 3.39586 |
| 1460 | 1587.63 | 537.1 | 1168.49 | 7.801 | 3.41247 |
| 1480 | 1611.79 | 568.8 | 1186.95 | 7.468 | 3.42892 |
| 1500 | 1635.97 | 601.9 | 1205.41 | 7.152 | 3.44516 |
| 1520 | 1660.23 | 636.5 | 1223.87 | 6.854 | 3.46120 |
| 1540 | 1684.51 | 672.8 | 1242.43 | 6.569 | 3.47712 |
| 1560 | 1708.82 | 710.5 | 1260.99 | 6.301 | 3.49276 |
| 1580 | 1733.17 | 750.0 | 1279.65 | 6.046 | 3.50829 |
| 1600 | 1757.57 | 791.2 | 1298.30 | 5.804 | 3.52364 |
| 1620 | 1782.00 | 834.1 | 1316.96 | 5.574 | 3.53879 |
| 1640 | 1806.46 | 878.9 | 1335.72 | 5.355 | 3.55381 |
| 1660 | 1830.96 | 925.6 | 1354.48 | 5.147 | 3.56867 |
| 1680 | 1855.50 | 974.2 | 1373.24 | 4.949 | 3.58335 |
| 1700 | 1880.1 | 1025 | 1392.7 | 4.761 | 3.5979 |
| 1750 | 1941.6 | 1161 | 1439.8 | 4.328 | 3.6336 |
| 1800 | 2003.3 | 1310 | 1487.2 | 3.994 | 3.6684 |
| 1850 | 2065.3 | 1475 | 1534.9 | 3.601 | 3.7023 |
| 1900 | 2127.4 | 1655 | 1582.6 | 3.295 | 3.7354 |
| 1950 | 2189.7 | 1852 | 1630.6 | 3.022 | 3.7677 |
| 2000 | 2252.1 | 2068 | 1678.7 | 2.776 | 3.7994 |
| 2050 | 2314.6 | 2303 | 1726.8 | 2.555 | 3.8303 |
| 2100 | 2377.7 | 2559 | 1775.3 | 2.356 | 3.8605 |
| 2150 | 2440.3 | 2837 | 1823.8 | 2.175 | 3.8901 |
| 2200 | 2503.2 | 3138 | 1872.4 | 2.012 | 3.9191 |
| 2250 | 2566.4 | 3464 | 1921.3 | 1.864 | 3.9474 |

*Note:* The properties $P_r$ (relative pressure) and $v_r$ (relative specific volume) are dimensionless quantities used in the analysis of isentropic processes, and should not be confused with the properties pressure and specific volume.

*Source:* Kenneth Wark, *Thermodynamics*, 4th ed. (New York: McGraw-Hill, 1983), pp. 785–86, table A–5. Originally published in J. H. Keenan and J. Kaye, *Gas Tables* (New York: John Wiley & Sons, 1948).

**Table A-6 Refrigerant 22: properties of liquid and saturated vapor[6]**

| | | Enthalpy, kJ/kg | | Entropy, kJ/kg · K | | Specific volume, L/kg | |
|---|---|---|---|---|---|---|---|
| t, °C | P, kPa | $h_f$ | $h_g$ | $s_f$ | $s_g$ | $v_f$ | $v_g$ |
| −60 | 37.48 | 134.763 | 379.114 | 0.73254 | 1.87886 | 0.68208 | 537.152 |
| −55 | 49.47 | 139.830 | 381.529 | 0.75599 | 1.86389 | 0.68856 | 414.827 |
| −50 | 64.39 | 144.959 | 383.921 | 0.77919 | 1.85000 | 0.69526 | 324.557 |
| −45 | 82.71 | 150.153 | 386.282 | 0.80216 | 1.83708 | 0.70219 | 256.990 |
| −40 | 104.95 | 155.414 | 388.609 | 0.82490 | 1.82504 | 0.70936 | 205.745 |
| −35 | 131.68 | 160.742 | 390.896 | 0.84743 | 1.81380 | 0.71680 | 166.400 |
| −30 | 163.48 | 166.140 | 393.138 | 0.86976 | 1.80329 | 0.72452 | 135.844 |
| −28 | 177.76 | 168.318 | 394.021 | 0.87864 | 1.79927 | 0.72769 | 125.563 |
| −26 | 192.99 | 170.507 | 394.896 | 0.88748 | 1.79535 | 0.73092 | 116.214 |
| −24 | 209.22 | 172.708 | 395.762 | 0.89630 | 1.79152 | 0.73420 | 107.701 |
| −22 | 226.48 | 174.919 | 396.619 | 0.90509 | 1.78779 | 0.73753 | 99.9362 |
| −20 | 244.83 | 177.142 | 397.467 | 0.91386 | 1.78415 | 0.74091 | 92.8432 |
| −18 | 264.29 | 179.376 | 398.305 | 0.92259 | 1.78059 | 0.74436 | 86.3546 |
| −16 | 284.93 | 181.622 | 399.133 | 0.93129 | 1.77711 | 0.74786 | 80.4103 |
| −14 | 306.78 | 183.878 | 399.951 | 0.93997 | 1.77371 | 0.75143 | 74.9572 |
| −12 | 329.89 | 186.147 | 400.759 | 0.94862 | 1.77039 | 0.75506 | 69.9478 |
| −10 | 354.30 | 188.426 | 401.555 | 0.95725 | 1.76713 | 0.75876 | 65.3399 |
| −9 | 367.01 | 189.571 | 401.949 | 0.96155 | 1.76553 | 0.76063 | 63.1746 |
| −8 | 380.06 | 190.718 | 402.341 | 0.06585 | 1.76394 | 0.76253 | 61.0958 |
| −7 | 393.47 | 191.868 | 402.729 | 0.97014 | 1.76237 | 0.76444 | 59.0996 |
| −6 | 407.23 | 193.021 | 403.114 | 0.97442 | 1.76082 | 0.76636 | 57.1820 |
| −5 | 421.35 | 194.176 | 403.496 | 0.97870 | 1.75928 | 0.76831 | 55.3394 |
| −4 | 435.84 | 195.335 | 403.876 | 0.98297 | 1.75775 | 0.77028 | 53.5682 |
| −3 | 450.70 | 196.497 | 404.252 | 0.98724 | 1.75624 | 0.77226 | 51.8653 |
| −2 | 465.94 | 197.662 | 404.626 | 0.99150 | 1.75475 | 0.77427 | 50.2274 |
| −1 | 481.57 | 198.828 | 404.994 | 0.99575 | 1.75326 | 0.77629 | 48.6517 |
| 0 | 497.59 | 200.000 | 405.361 | 1.00000 | 1.75279 | 0.77834 | 47.1354 |
| 1 | 514.01 | 201.174 | 405.724 | 1.00424 | 1.75034 | 0.78041 | 45.6757 |
| 2 | 530.83 | 202.351 | 406.084 | 1.00848 | 1.74889 | 0.78249 | 44.2702 |
| 3 | 548.06 | 203.530 | 406.440 | 1.01271 | 1.74746 | 0.78460 | 42.9166 |
| 4 | 565.71 | 204.713 | 406.793 | 1.01694 | 1.74604 | 0.78673 | 41.6124 |
| 5 | 583.78 | 205.899 | 407.143 | 1.02116 | 1.74463 | 0.78889 | 40.3556 |
| 6 | 602.28 | 207.089 | 407.489 | 1.02537 | 1.74324 | 0.79107 | 39.1441 |
| 7 | 621.22 | 208.281 | 407.831 | 1.02958 | 1.74185 | 0.79327 | 37.9759 |
| 8 | 640.59 | 209.477 | 408.169 | 1.03379 | 1.74047 | 0.79549 | 36.8493 |
| 9 | 660.42 | 210.675 | 408.504 | 1.03799 | 1.73911 | 0.79775 | 35.7624 |
| 10 | 680.70 | 211.877 | 408.835 | 1.04218 | 1.73775 | 0.80002 | 34.7136 |
| 11 | 701.44 | 213.083 | 409.162 | 1.04637 | 1.73640 | 0.80232 | 33.7013 |
| 12 | 722.65 | 214.291 | 409.485 | 1.05056 | 1.73506 | 0.80465 | 32.7239 |
| 13 | 744.33 | 215.503 | 409.804 | 1.05474 | 1.73373 | 0.80701 | 31.7801 |
| 14 | 766.50 | 216.719 | 410.119 | 1.05892 | 1.73241 | 0.80939 | 30.8683 |
| 15 | 789.15 | 217.937 | 410.430 | 1.06309 | 1.73109 | 0.81180 | 29.9874 |
| 16 | 812.29 | 219.160 | 410.736 | 1.06726 | 1.72978 | 0.81424 | 29.1361 |
| 17 | 835.93 | 220.386 | 411.038 | 1.07142 | 1.72848 | 0.81671 | 28.3131 |
| 18 | 860.08 | 221.615 | 411.336 | 1.07559 | 1.72719 | 0.81922 | 27.5173 |
| 19 | 884.75 | 222.848 | 411.629 | 1.07974 | 1.72590 | 0.82175 | 26.7477 |
| 20 | 909.93 | 224.084 | 411.918 | 1.08390 | 1.72462 | 0.82431 | 26.0032 |

**Table A-6 (continued)**

| | | Enthalpy, kJ/kg | | Entropy, kJ/kg · K | | Specific volume, L/kg | |
|---|---|---|---|---|---|---|---|
| t, °C | P, kPa | $h_f$ | $h_g$ | $s_f$ | $s_g$ | $v_f$ | $v_g$ |
| 21 | 935.64 | 225.324 | 412.202 | 1.08805 | 1.72334 | 0.82691 | 25.2829 |
| 22 | 961.89 | 226.568 | 412.481 | 1.09220 | 1.72206 | 0.82954 | 24.5857 |
| 23 | 988.67 | 227.816 | 412.755 | 1.09634 | 1.72080 | 0.83221 | 23.9107 |
| 24 | 1016.0 | 229.068 | 413.025 | 1.10048 | 1.71953 | 0.83491 | 23.2572 |
| 25 | 1043.9 | 230.324 | 413.289 | 1.10462 | 1.71827 | 0.83765 | 22.6242 |
| 26 | 1072.3 | 231.583 | 413.548 | 1.10876 | 1.71701 | 0.84043 | 22.0111 |
| 27 | 1101.4 | 232.847 | 413.802 | 1.11290 | 1.71576 | 0.84324 | 21.4169 |
| 28 | 1130.9 | 234.115 | 414.050 | 1.11703 | 1.71450 | 0.84610 | 20.8411 |
| 29 | 1161.1 | 235.387 | 414.293 | 1.12116 | 1.71325 | 0.84899 | 20.2829 |
| 30 | 1191.9 | 236.664 | 414.530 | 1.12530 | 1.71200 | 0.85193 | 19.7417 |
| 31 | 1223.2 | 237.944 | 414.762 | 1.12943 | 1.71075 | 0.85491 | 19.2168 |
| 32 | 1255.2 | 239.230 | 414.987 | 1.13355 | 1.70950 | 0.85793 | 18.7076 |
| 33 | 1287.8 | 240.520 | 415.207 | 1.13768 | 1.70826 | 0.86101 | 18.2135 |
| 34 | 1321.0 | 241.814 | 415.420 | 1.14181 | 1.70701 | 0.86412 | 17.7341 |
| 35 | 1354.8 | 243.114 | 415.627 | 1.14594 | 1.70576 | 0.86729 | 17.2686 |
| 36 | 1389.2 | 244.418 | 415.828 | 1.15007 | 1.70450 | 0.87051 | 16.8168 |
| 37 | 1424.3 | 245.727 | 416.021 | 1.15420 | 1.70325 | 0.87378 | 16.3779 |
| 38 | 1460.1 | 247.041 | 416.208 | 1.15833 | 1.70199 | 0.87710 | 15.9517 |
| 39 | 1496.5 | 248.361 | 416.388 | 1.16246 | 1.70073 | 0.88048 | 15.5375 |
| 40 | 1533.5 | 249.686 | 416.561 | 1.16659 | 1.69946 | 0.88392 | 15.1351 |
| 41 | 1571.2 | 251.016 | 416.726 | 1.17073 | 1.69819 | 0.88741 | 14.7439 |
| 42 | 1609.6 | 252.352 | 416.883 | 1.17486 | 1.69692 | 0.89097 | 14.3636 |
| 43 | 1648.7 | 253.694 | 417.033 | 1.17900 | 1.69564 | 0.89459 | 13.9938 |
| 44 | 1688.5 | 255.042 | 417.174 | 1.18315 | 1.69435 | 0.89828 | 13.6341 |
| 45 | 1729.0 | 256.396 | 417.308 | 1.18730 | 1.69305 | 0.90203 | 13.2841 |
| 46 | 1770.2 | 257.756 | 417.432 | 1.19145 | 1.69174 | 0.90586 | 12.9436 |
| 47 | 1812.1 | 259.123 | 417.548 | 1.19560 | 1.69043 | 0.90976 | 12.6122 |
| 48 | 1854.8 | 260.497 | 417.655 | 1.19977 | 1.68911 | 0.91374 | 12.2895 |
| 49 | 1898.2 | 261.877 | 417.752 | 1.20393 | 1.68777 | 0.91779 | 11.9753 |
| 50 | 1942.3 | 263.264 | 417.838 | 1.20811 | 1.68643 | 0.92193 | 11.6693 |
| 52 | 2032.8 | 266.062 | 417.983 | 1.21648 | 1.68370 | 0.93047 | 11.0806 |
| 54 | 2126.5 | 268.891 | 418.083 | 1.22489 | 1.68091 | 0.93939 | 10.5214 |
| 56 | 2223.2 | 271.754 | 418.137 | 1.23333 | 1.67805 | 0.94872 | 9.98952 |
| 58 | 2323.2 | 274.654 | 418.141 | 1.24183 | 1.67511 | 0.95850 | 9.48319 |
| 60 | 2426.6 | 277.594 | 418.089 | 1.25038 | 1.67208 | 0.96878 | 9.00062 |
| 62 | 2533.3 | 280.577 | 417.978 | 1.25899 | 1.66895 | 0.97960 | 8.54016 |
| 64 | 2643.5 | 283.607 | 417.802 | 1.26768 | 1.66570 | 0.99104 | 8.10023 |
| 66 | 2757.3 | 286.690 | 417.553 | 1.27647 | 1.66231 | 1.00317 | 7.67934 |
| 68 | 2874.7 | 289.832 | 417.226 | 1.28535 | 1.65876 | 1.01608 | 7.27605 |
| 70 | 2995.9 | 293.038 | 416.809 | 1.29436 | 1.65504 | 1.02987 | 6.88899 |
| 75 | 3316.1 | 301.399 | 415.299 | 1.31758 | 1.64472 | 1.06916 | 5.98334 |
| 80 | 3662.3 | 310.424 | 412.898 | 1.34223 | 1.63239 | 1.11810 | 5.14862 |
| 85 | 4036.8 | 320.505 | 409.101 | 1.36936 | 1.61673 | 1.18328 | 4.35815 |
| 90 | 4442.5 | 332.616 | 402.653 | 1.40155 | 1.59440 | 1.28230 | 3.56440 |
| 95 | 4883.5 | 351.767 | 386.708 | 1.45222 | 1.54712 | 1.52064 | 2.55133 |

## Refrigerant 22: properties of superheated vapor[6]

| T | v, L/kg | h, kJ/kg | s, kJ/kg · K | v, L/kg | h, kJ/kg | s, kJ/kg · K | v, L/kg | h, kJ/kg | s, kJ/kg · K |
|---|---|---|---|---|---|---|---|---|---|
| | Saturation temperature, −20°C | | | Saturation temperature, −10°C | | | Saturation temperature, 0°C | | |
| −20 | 92.8432 | 397.467 | 1.7841 | | | | | | |
| −15 | 95.1474 | 400.737 | 1.7969 | | | | | | |
| −10 | 97.4256 | 404.017 | 1.8095 | 65.3399 | 401.555 | 1.7671 | | | |
| −5 | 99.6808 | 407.307 | 1.8219 | 67.0081 | 404.983 | 1.7800 | | | |
| 0 | 101.915 | 410.610 | 1.8341 | 68.6524 | 408.412 | 1.7927 | 47.1354 | 405.361 | 1.7518 |
| 5 | 104.130 | 413.926 | 1.8461 | 70.2751 | 411.845 | 1.8052 | 48.3899 | 408.969 | 1.7649 |
| 10 | 106.328 | 417.258 | 1.8580 | 71.8785 | 415.283 | 1.8174 | 49.6215 | 412.567 | 1.7777 |
| 15 | 108.510 | 420.606 | 1.8697 | 73.4644 | 418.730 | 1.8295 | 50.8328 | 416.159 | 1.7903 |
| 20 | 110.678 | 423.970 | 1.8813 | 75.0346 | 422.186 | 1.8414 | 52.0259 | 419.649 | 1.8026 |
| 25 | 112.832 | 426.353 | 1.8928 | 76.5904 | 425.653 | 1.8531 | 53.2028 | 423.339 | 1.8148 |
| | Saturation temperature, 5°C | | | Saturation temperature, 10°C | | | Saturation temperature, 15°C | | |
| 5 | 40.3556 | 407.143 | 1.7446 | | | | | | |
| 10 | 41.4580 | 410.851 | 1.7578 | 34.7136 | 408.835 | 1.7377 | | | |
| 15 | 42.5379 | 414.542 | 1.7708 | 35.6907 | 412.651 | 1.7511 | 29.9874 | 410.430 | 1.7311 |
| 20 | 43.5979 | 418.222 | 1.7834 | 36.6454 | 416.442 | 1.7642 | 30.8606 | 414.362 | 1.7556 |
| 25 | 44.6401 | 421.894 | 1.7958 | 37.5804 | 420.215 | 1.7769 | 31.7114 | 418.260 | 1.7578 |
| 30 | 45.6665 | 425.562 | 1.8080 | 38.4981 | 423.974 | 1.7894 | 32.5427 | 422.133 | 1.7707 |
| 35 | 46.6786 | 429.229 | 1.8200 | 39.4002 | 427.724 | 1.8017 | 33.3568 | 425.985 | 1.7833 |
| 40 | 47.6779 | 432.897 | 1.8319 | 40.2884 | 431.469 | 1.8137 | 34.1556 | 429.823 | 1.7956 |
| 45 | 48.6656 | 436.569 | 1.8435 | 41.1642 | 435.211 | 1.8256 | 34.9409 | 433.650 | 1.8078 |
| 50 | 49.6427 | 440.247 | 1.8550 | 42.0286 | 438.954 | 1.8373 | 35.7139 | 437.470 | 1.8197 |

**Table A-7 (continued)**

| T | v, L/kg | h, kJ/kg | s, kJ/kg · K | v, L/kg | h, kJ/kg | s, kJ/kg · K | v, L/kg | h, kJ/kg | s, kJ/kg · K |
|---|---|---|---|---|---|---|---|---|---|
| | Saturation temperature, 20°C | | | Saturation temperature, 25°C | | | Saturation temperature, 30°C | | |
| 20 | 26.0032 | 411.918 | 1.7246 | | | | | | |
| 25 | 26.7900 | 415.977 | 1.7383 | 22.6242 | 413.289 | 1.7183 | | | |
| 30 | 27.5542 | 419.991 | 1.7517 | 23.3389 | 417.487 | 1.7322 | 19.7417 | 414.530 | 1.7120 |
| 35 | 28.2989 | 423.970 | 1.7646 | 24.0306 | 421.627 | 1.7458 | 20.3962 | 418.881 | 1.7262 |
| 40 | 29.0264 | 427.922 | 1.7774 | 24.7027 | 425.721 | 1.7590 | 21.0272 | 423.159 | 1.7400 |
| 45 | 29.7389 | 431.852 | 1.7899 | 25.3575 | 429.779 | 1.7718 | 21.6381 | 427.378 | 1.7534 |
| 50 | 30.4379 | 435.766 | 1.8021 | 25.9974 | 433.807 | 1.7844 | 22.2316 | 431.549 | 1.7664 |
| 55 | 31.1250 | 439.668 | 1.8141 | 26.6239 | 437.813 | 1.7967 | 22.8101 | 435.683 | 1.7791 |
| 60 | 31.8012 | 443.561 | 1.8258 | 27.2386 | 441.801 | 1.8087 | 23.3733 | 439.787 | 1.7915 |
| 65 | 32.4678 | 447.450 | 1.8374 | 27.8427 | 445.777 | 1.8206 | 23.9288 | 443.867 | 1.8036 |
| | Saturation temperature, 32°C | | | Saturation temperature, 34°C | | | Saturation temperature, 36°C | | |
| 35 | 19.0907 | 417.648 | 1.7182 | 17.8590 | 416.325 | 1.7099 | | | |
| 40 | 19.7093 | 422.014 | 1.7322 | 18.4675 | 420.792 | 1.7243 | 17.2953 | 419.483 | 1.7162 |
| 45 | 20.3062 | 426.310 | 1.7458 | 19.0526 | 425.174 | 1.7382 | 17.8708 | 423.961 | 1.7304 |
| 50 | 20.8847 | 430.549 | 1.7591 | 19.6178 | 429.487 | 1.7517 | 18.4247 | 428.358 | 1.7442 |
| 55 | 21.4471 | 434.743 | 1.7719 | 20.1660 | 433.747 | 1.7647 | 18.9603 | 432.690 | 1.7575 |
| 60 | 21.9956 | 438.900 | 1.7845 | 20.6994 | 437.963 | 1.7775 | 19.4802 | 436.970 | 1.7704 |
| 65 | 22.5318 | 443.028 | 1.7968 | 21.2199 | 442.143 | 1.7899 | 19.9865 | 441.207 | 1.7830 |
| 70 | 23.0571 | 447.133 | 1.8089 | 21.7289 | 446.294 | 1.8021 | 20.4807 | 445.410 | 1.7954 |
| 75 | 23.5726 | 451.219 | 1.8207 | 22.2278 | 450.424 | 1.8141 | 20.9643 | 449.586 | 1.8074 |
| 80 | 24.0794 | 455.292 | 1.8323 | 22.7176 | 454.535 | 1.8258 | 21.4385 | 453.739 | 1.8193 |