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ESE 2024 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Mechanical Engineering

Test-1 : Thermodynamics [All Topics]

Strength of Materials & Mechanics [All Topics]

Name :

Roll No :

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
Pune ☐	Kolkata ☐	Hyderabad ☐	

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	44
Q.2	45
Q.3	—
Q.4	47
Section-B	
Q.5	1
Q.6	8
Q.7	—
Q.8	—
Total Marks Obtained	145

Signature of Evaluator .... Cross Checked by ....

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Remarks:-

- Mention the units properly to avoid silly mistakes.
- Improve the presentation of writing the solutions.

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Section : A

Q.1 (a) The exhaust gas at 720°C from a boiler is used to heat water. The rate of gas flow is 1450 kg/min and the rate of water flow is 2000 kg/min. The water enters the heat exchanger at 42°C and the gases leave the exchanger at 160°C. Assume that the mean specific heat of gas and water are 1.088 kJ/kgK and 4.27 kJ/kgK respectively.

The atmospheric temperature is 27°C. Determine the loss of available energy resulting from heat transfer. Assuming Exhaust gas to behave as Ideal Gas :-

[12 marks]

for Exhaust gas, $T_1 = 720°C$, $m_1 = 1450\,kg/min$, $t_2 = 160°C$.
$c_{p_1} = 1.088\,kJ/kgK$.

for water, $T_3 = 42°C$, $m_2 = 2000\,kg/min$, $(C_p)_w = 4.27\,kJ/kgK$

By Energy Conservation (assuming all heat from gas goes to water)

$(mc_p\Delta T)_{gas} = (mc_p\Delta T)_{water} \Rightarrow 1450 \times 1.088[720-160] = 2000 \times 4.27 \times [t_4 - 42]$

outlet temp of water, $\boxed{t_4 = 145.45°C}$

ambient condition = $T_0 = 300K$.

change in availability of gases from going from 720°C to 160°C.

$= (h_1 - T_0 s_1) - (h_2 - T_0 s_2)$

$= (h_1 - h_2) + T_0(s_2 - s_1)$

$\phi_1 - \phi_2 = \frac{1450}{60}\left[1.088[720-160]\right] + 300 \times \frac{1450}{60}\left[1.088 \ln\frac{433}{993} - R\ln\frac{P_2}{P_1}\right]$

assuming heat transfer takes place at Constant Pressure,

$\ln\frac{P_2}{P_1} = 0$.

$\phi_1 - \phi_2 = 8.18\,MJ$

for water

change in availability for $\Rightarrow (h_4 - T_0 s_4) - (h_3 - T_0 s_3)$

$= (h_4 - h_3) - T_0[s_4 - s_3]$

$= \frac{2000}{60}\left[4.27[145.45-42] - 300 \times \left[4.27 \ln\frac{418.45}{315}\right]\right]$

$= 2.567\,MJ$

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So, loss of available Energy due to heat transfer = ~~the~~ [Loss in available Energy of gas] − [Gain in the available Energy of water]

$= 8.18 - 2.567$

$= \boxed{5.913 \text{ MJ.}}$

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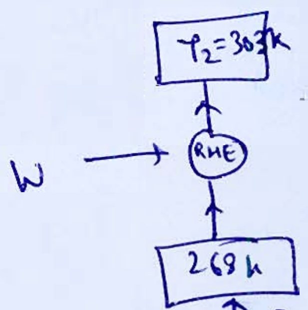
Q.1 (b) A household refrigerator maintains a space at a temperature of –5°C. Every time the door is opened, warm material is placed inside, introducing an average 500 kJ of heat, but making only a small change in temperature of the refrigerator. The door is opened 30 times a day and the refrigerator operates at 25% of ideal COP. The cost of work is ₹2.5 per kWh. What is the yearly bill of this refrigerator? The atmospheric temperature is at 30°C.

[12 marks]

Temp of Refrigerated Space = $-5^\circ C = 268$ K.



$Q_1 = 500$ kJ / opening.

$\therefore (COP)_{ideal} = \frac{T_L}{T_H - T_L} = \frac{268}{35} = 7.657.$

Actual COP = $(.25)(COP)_{ideal}$

$\boxed{(COP)_{actual} = 1.914}$

As the Refrigerator is ~~opened~~ 30 times a day,
So, amount of heat input/day = 500 × 30 = 15000 kJ/day

So, for a ~~month~~ year, heat input, Q_1 = 15000 × 365 kJ.

So, $\left(COP_{actual} = \frac{Q_1}{W_{input}}\right) \Rightarrow W_{input} = \frac{15000 \times 365}{1.914}$

$$\boxed{W_{input} = 2860.501 \text{ MJ}}$$

As the Cost of Electricity is Rs 2.5 for 1 kWh.
i.e 3600 kJ

So, 3600 → Rs 2.5

1 → $\frac{2.5}{3600}$

$2860.501 \times 10^3 \rightarrow \frac{2.5 \times 2860.501 \times 10^3}{3600}$

$$\boxed{\text{Total yearly cost} = \text{Rs } 1986.45}$$

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Q.1 (c) A cylinder contains 0.15 m^3 of air at 1 bar and 80°C. It is compressed to 0.02 m^3, during a polytropic process the final pressure being 12 bar. Calculate the increase in internal energy and heat transferred during compression.

[12 marks]

Initial Condition → Compression → Final Condition

$V_1 = .15 m^3$; $V_2 = .02 m^3$

$P_1 = 1$ bar ; $P_2 = 12$ bar

$T_1 = 353$ K ; T_2

Let n be the index of polytropic compression,

So, $PV^n = C$

i.e. $\Rightarrow P_1 V_1^n = P_2 V_2^n$

$(1)[.15]^n = (12)(.02)^n$

$(7.5)^n = 12 \Rightarrow n \ln 7.5 = \ln 12$

$$\boxed{n = 1.233}$$

Using $PV = mRT$ (for ideal gas assumption),

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow T_2 = \left(\frac{P_2}{P_1}\right)\left(\frac{V_2}{V_1}\right) T_1 = \left(\frac{12}{1}\right)\left[\frac{.02}{.15}\right](353)$

$\boxed{T_2 = 564.8 K}$

~~Increase in Inte~~ also, $P_1 V_1 = mRT_1$

$\Rightarrow m = \frac{P_1 V_1}{RT_1} = \frac{(100)(.15)}{.287 \times 353}$

$\boxed{m = .148 \text{ Kg}}$

Increase in Internal Energy

$U_2 - U_1 = m C_v [T_2 - T_1]$

$= .148 \times .718 [564.8 - 353]$

$\boxed{\Delta U = 22.506 \text{ kJ}}$

~~Work transfer during the process~~

Heat transfer during the Compression :→

* work transfer during the Compression $= \frac{P_2 V_2 - P_1 V_1}{n-1}$

$= \frac{1200 \times .02 - (100)(.15)}{.233} = 38.626 \text{ kJ}.$

By 1st law of thermodynamics

$\Delta Q = \Delta U + \Delta W$

$= 22.506 - 38.626$

$\boxed{\Delta Q = -16.12 \text{ kJ}}$ → Rejection

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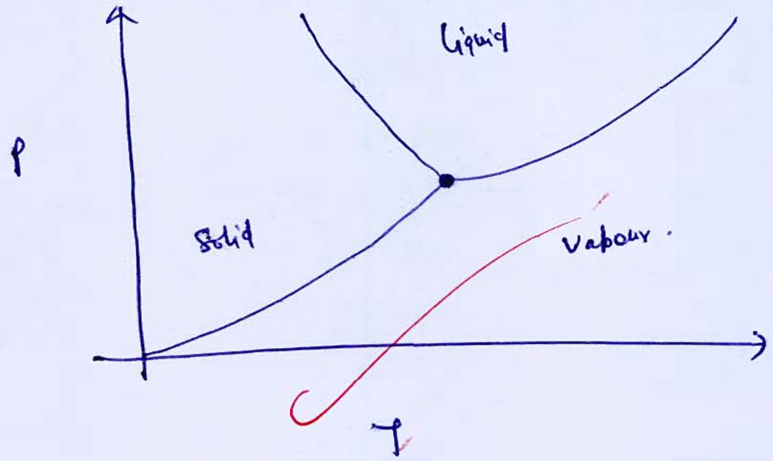
Q.1 (d) Sketch a P-T phase diagram for water and indicate the solid, liquid and vapour regions on it. Explain how this diagram differs from the phase diagram of other substances.

[12 marks]

P-T phase diagram for water



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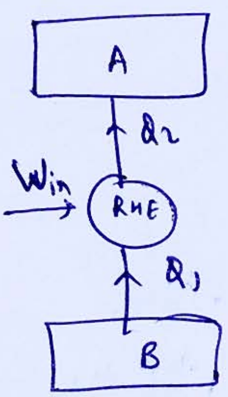
Water has a peculiar behaviour, that upon melting, from solid to liquid, its volume decreases unlike any other substance, where the volume increases upon melting.

So, for water, $\left.\frac{dP}{dT}\right|_{solid \to liquid}$ is negative, whereas the slope of P-T for other substances are positive.

Q.1 (e) Two identical bodies of same heat capacity are at the same initial temperature T_1. A reversible refrigerator operates between these two bodies, until one body is cooled to the temperature T_2. If the bodies are at constant temperatures and do not undergo any change of phase, prove that the minimum amount of work needed by refrigerator is

$$W_{in} = C_p\left[\frac{T_1^2}{T_2} + T_2 - 2T_1\right]$$

12 marks]



Initial temp of both bodies $= T_1$

Heat Capacity, $C_A = C_B = C$ [given]

as final temp of body $B = T_2$.

let W_{in} be the amount of work consumed by the Refrigerator.

for the Minimum work, the Heat Engine should work Reversibly, and hence $(\Delta S)_{universe} = 0$.

so, $(\Delta S)_A + (\Delta S)_{H.E} + (\Delta S)_B = 0$

as Heat Engine is a cyclic process, $(\Delta S)_{H.E} = 0$.

So, $\boxed{(\Delta S)_A + (\Delta S)_B = 0}$ — (1)

Amount of heat taken out from B to cool it from T_1 to T_2

$$\boxed{Q_1 = C[T_1 - T_2]}$$

amount of heat gain by Body A = $W + Q_1$

Let T_f be the final temp of 'A',

So, $C[T_f - T_1] = W_{in} + C[T_1 - T_2]$

$$T_f - T_1 = \frac{W_{in}}{C} + (T_1 - T_2)$$

$$\boxed{T_f = \frac{W_{in}}{C} + 2T_1 - T_2} \quad -(2)$$

from (1), $(\Delta S)_A + (\Delta S)_B = 0$

$$C \ln\frac{T_f}{T_1} - C\ln\frac{T_1}{T_2} = 0 \quad \text{as} \quad \boxed{T_f = \frac{T_1^2}{T_2}} \; -(3)$$

from (2) and (3)

$$\frac{W_{in}}{C} + 2T_1 - T_2 = \frac{T_1^2}{T_2}.$$

$$\frac{W_{in}}{C} = \frac{T_1^2}{T_2} + T_2 - 2T_1$$

$$\boxed{(W_{input})_{min} = C\left[\frac{T_1^2}{T_2} + T_2 - 2T_1\right]}$$

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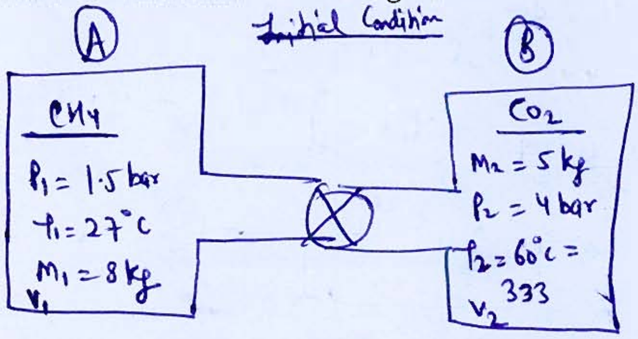
Q.2 (a) A tank containing 8 kg of methane at 1.5 bar and 27°C is connected to another tank containing 5 kg of CO_2 at 4 bar and 60°C through a valve. The valve is opened and the gases mix adiabatically. Determine the final pressure and temperature of the mixture and the irreversibility of the process, when environment temperature is 27°C. Given constant pressure specific heat of methane = 2.1 kJ/kgK and that of CO_2 = 0.85 kJ/kgK. Treat both the constituents as ideal gas.

[20 marks]

Initial Condition



Using Ideal Gas Relation, $PV = MRT$

Volume of tank A, V_1 =)

$\boxed{R_{CH_4} = \frac{\bar{R}}{M_{CH_4}} = \frac{8.314}{16}}$, $P_1 V_1 = M_1 R T_1 \Rightarrow V_1 = (8)\left(\frac{8.314}{16}\right)\frac{\times 300}{1.5 \times 100}$

$$\boxed{V_1 = 8.314 \text{ m}^3}$$

Volume of tank B, V_2 ⇒

$$R_{CO_2} = \frac{\bar{R}}{M_{CO_2}} = \frac{8.314}{44}$$

$$V_2 = \frac{M_2 R T_2}{P_2} = (5)\left(\frac{8.314}{44}\right)\frac{\times 333}{400}$$

$$\boxed{V_2 = .786 \text{ m}^3}$$

no. of moles of CH_4, $n_1 = \frac{m_1}{M_1} = \frac{8}{16} = 0.5$ kg-mol

no. of moles of CO_2, $n_2 = \frac{m_2}{M_2} = \frac{5}{44} = .1136$ kgmol

upon Mixing, let final pressure and temp be P_f, T_f.

As mixing is adiabatic, So, by energy Conservation,

~~$U_1 + U_2 = U_f$~~

~~Heat lost by CO_2 = Heat gain by Methane~~

~~$M_2 C$~~ as the system is closed system,

$$\boxed{\underbrace{U_1}_{\text{Methane}} + \underbrace{U_2}_{CO_2} = \underbrace{U_f}_{\text{Mixed condition}} \quad — (1)}$$

$(C_p)_{CH_4} = 2.1\ kJ/kgK$, $[C_p - C_v = R]_{methane}$

$C_v = 2.1 - \frac{8.314}{16} \Rightarrow$ $\boxed{(C_v)_{CH_4} = 1.58\ kJ/kgK}$

$(C_p)_{CO_2} = 0.85\ kJ/kgK$; $C_v = (C_p - R)_{CO_2} = .85 - \frac{8.314}{44} \Rightarrow$

$$\boxed{(C_v)_{CO_2} = .66\ kJ/kgK}$$

So, from (1)

$$M_1 (C_v)_{CH_4} T_1 + M_2 (C_v)_{CO_2} T_2 = M_1 (C_v)_{CH_4} T_f + M_2 (C_v)_{CO_2} T_f .$$

$$T_f = \frac{(8)(1.58)[300] + (5)(.66)[333]}{(8)(1.58) + (5)(.66)}$$

$$\boxed{T_f = 306.83\ K} \rightarrow \text{Answer}$$

Now using $PV = n\bar{R}T$

$(P_f) V_f = (n_1 + n_2) \bar{R} T_f$.

here $V_f = V_1 + V_2 = 8.314 + .786 = 9.1 m^3$.

So, $(P_f)[9.1] = (n_1 + n_2) \bar{R} (T_f)$

$(P_f)(9.1) = (.5 + .1136)(8.314)(306.83)$

$$\boxed{P_f = 1.72\ bar} \rightarrow \text{Answer}$$

Irreversibility of the process :-

$(\Delta S)_{universe} = (\Delta S)_{system} + (\Delta S)_{surroundings}^{\nearrow 0}$ [as no heat is transferred to the surrounding]

$\downarrow$ taking tanks as system.

$(\Delta S)_{system} = S_f - (S_1 + S_2) = (\Delta S)_{CH_4} + (\Delta S)_{CO_2}$.

P_{f1}, Partial Pressure of Methane upon mixing $= \left(\frac{n_1}{n_1+n_2}\right) P_f = \left(\frac{.5}{.5+.1136}\right) 1.72 = 1.401$ bar

P_{f2}, Partial Pressure of CO_2 upon mixing $= \left(\frac{n_2}{n_1+n_2}\right) P_f = \left(\frac{.1136}{.5+.1136}\right) 1.72 = .318$ bar

$$(\Delta S)_{CH_4} = m_1 \left[C_p \ln \frac{T_f}{T_1} - R \ln \frac{P_{f1}}{P_1} \right]$$

$$(\Delta S)_{CH_4} = [8] \left[2.1 \ln \frac{306.83}{300} - \frac{8.314}{16} \ln \frac{1.401}{1.5} \right] = .662 \text{ kJ/k}.$$

$$\boxed{(\Delta S)_{CH_4} = .662 \text{ kJ/k}}$$

$$(\Delta S)_{CO_2} = m_2 \left[C_p \ln \frac{T_f}{T_2} - R \ln \frac{P_{f2}}{P_2} \right]$$

$$= [5] \left[.85 \ln \frac{306.83}{333} - \frac{8.314}{44} \ln \frac{.318}{4} \right]$$

$$\boxed{(\Delta S)_{CO_2} = 2.044 \text{ kJ/k}.}$$

$(\Delta S)_{universe} = (\Delta S)_{CH_4} + (\Delta S)_{CO_2} = .622 + 2.044$

$(\Delta S)_{universe} = 2.666$ kJ/k.

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$\dot{I} = T_0 (\Delta S)_{universe}$

$= (300)[2.666] = 799.8 \simeq 800$ kJ

$$\boxed{\dot{I} = 799.8 \simeq 800 \text{ kJ}}$$

Q.2 (b) The steam enters at steam turbine at 4 MPa and 500°C at a rate of 8 kg/s and exits at 0.3 MPa and 170°C. The steam is losing heat to the surroundings at 100 kPa and 25°C at a rate of 400 kW. The changes in kinetic and potential energies are negligible. Calculate

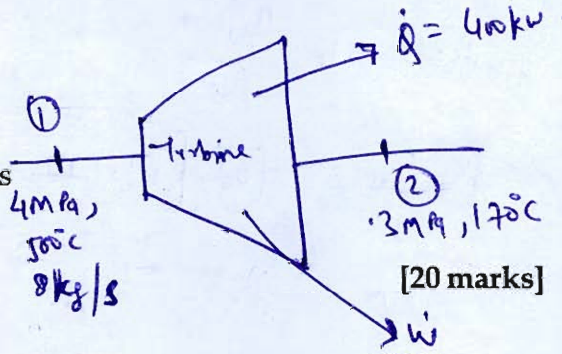
(i) actual power output

(ii) the reversible work

(ii) second law efficiency

(iv) the availability of steam at inlet conditions

[Refer steam table attached]



[20 marks]

~~for look~~ To

Atmospheric Condition ∃ $T_0 = 298$ k

$P_0 = 100$ kPa.

for the Condition of Steam at ① [Inlet]

at 4 MPa, $T_{sat} = 250.354°C < 500°C$

So, the Steam is Superheated at Inlet to the turbine, so, from steam table,

$\boxed{h_1 = 3446 \text{ kJ/kg}}$, $\boxed{S_1 = 7.0922 \text{ kJ/kgK}}$.

for the Condition of Steam at ②, (outlet)

at 0.3MPa, $T_{sat} = 133.522°C < 170°C$, so, the

Steam is superheated at outlet also,

so, for 0.3 MPa, 170°C,

$\boxed{h_2 = 2803.2 \text{ kJ/kg}}$ $\boxed{S_2 = 7.1773 \text{ kJ/kgK}}$

① Actual Power output :-

By energy Conservation, (neglecting change in KE and PE).

$\dot{m}(h_1) - \dot{Q} - \dot{W} = \dot{m} h_2$

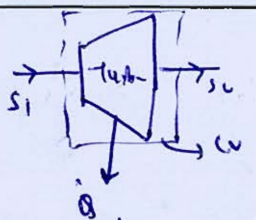
$\dot{W} = \dot{m}(h_1 - h_2) - \dot{Q}$

$= (8)[3446 - 2803.2] - 400$

$\boxed{\dot{W}_{actual} = 4.7384 \text{ MJ}}$

(ii) Reversible work (Wmax)

Irreversibility in the Process, $\dot{I} = T_0 (\Delta S)_{universe} = T_0 (\Delta S)_{gen}$.



$\frac{dS_{cv}}{dt} = S_1 + S_{gen} - S_2 - \frac{Q}{T_0}$.

[Assuming Heat loss from Turbine occurs at $T_0 = 298\,K$].

for steady state, $\frac{dS_{cv}}{dt} = 0 \Rightarrow S_{gen} = S_2 + \frac{Q}{T_0} - S_1$

$$S_{gen} = (8)\left[7.1773 - 7.0322\right] + \frac{400}{298}$$

$$\boxed{S_{gen} = 2.023\ kJ/K}$$

$$\dot{I} = T_0 S_{gen} = (298)(2.023) = 602.854\ kJ.$$

So, Reversible Work, $W_{max} = W_{act} + I$

$= 4738.4 + 602.854$

$W_{max} = 5341.254\ kJ$

$$\boxed{W_{max} = 5.341\ MJ}$$

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(iii) η_{II}

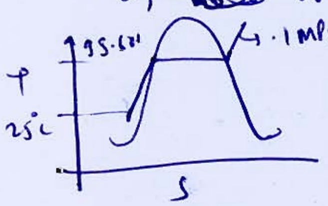
$$\eta_{II} = \frac{W_{actual}}{W_{max}} = \frac{4.738}{5.341} = 88.709\,\%$$

(iv) availability of steam at initial condition :-

at atmospheric condition, 0.1 MPa, ~~298~~ $T_{sat} = 99.61°C$ ~~298~~, so,

at the atmospheric condition, steam is ~~saturated~~ subcooled.

~~so, h0 at atmospheric condition, h0 |T=298 ≃ h0 |T=100°C~~



So, condition of steam at .1 MPa, 25°C can be taken as condition of saturated water at 25°C

So, $h_0 = h_f = 104.83\ kJ/kg$, $S_0 = S_f = .3672\ kJ/kgK$.

So, availability of steam at inlet :- $\dot{m}\left[(h_1 - T_0 S_1) - (h_0 - T_0 S_0)\right]$.

$= \left[(h_1 - h_0) + T_0 (S_0 - S_1)\right]\dot{m}$

$= \left[(3446 - 104.83) + 298\left[.36722 - 7.0322\right]\right](8)$

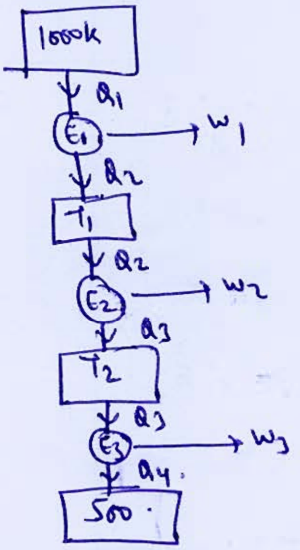
$= 10.697\ MJ$ [answer].

Q.2 (c) Three Carnot engines E_1, E_2 and E_3 operate in series between two heat reservoirs, which are at temperatures of 1000 K and 500 K. Calculate the temperature of the intermediate reservoirs if the amount of work produced by these engines in the proportion of 7 : 5 : 4.

[20 marks]

Given

$W_1 : W_2 : W_3 = 7 : 5 : 4$



$\boxed{\text{for Carnot Engine 1,}}$

$$\eta_{E_1} = 1 - \frac{T_1}{1000}.$$

$$\&, \quad 1 - \frac{T_1}{1000} = \frac{W_1}{Q_1}$$

$$\boxed{W_1 = \left(1 - \frac{T_1}{1000}\right) Q_1}$$

now $Q_2 = Q_1 - W_1 = Q_1 - \left(1 - \frac{T_1}{1000}\right) Q_1 \Rightarrow Q_1 \frac{T_1}{1000}$.

$$\boxed{Q_2 = Q_1 \frac{T_1}{1000}}$$

for Carnot Engine 2

$$\eta_{E_2} = 1 - \frac{T_2}{T_1} = \frac{W_2}{Q_2}.$$

$$\boxed{W_2 = \left(1 - \frac{T_2}{T_1}\right)\left(Q_2 \right) = \left(1 - \frac{T_2}{T_1}\right)\left(Q_1 \frac{T_1}{1000}\right)}$$

also, $Q_3 = Q_2 - W_2 = Q_2 - \left(1 - \frac{T_2}{T_1}\right) Q_2$

$$= Q_2 \frac{T_2}{T_1}.$$

$$\&, \quad \boxed{Q_3 = Q_1 \left(\frac{T_1}{1000}\right)\left(\frac{T_2}{T_1}\right)} \Rightarrow \boxed{Q_3 = Q_1 \frac{T_2}{1000}}$$

~~for Carnot Engine 3,~~ $\cancel{\eta_{E_3} = 1 - \frac{500}{T_2} = \frac{W_3}{Q_3}}$.

$$\cancel{\boxed{W_3 = \left(1 - \frac{500}{T_2}\right) Q_1 \left(\frac{T_2}{1000}\right)}}$$

for Carnot Engine 3 $\eta_{E3} = 1 - \frac{500}{T_2} = \frac{W_3}{Q_3}$.

$$W_3 = \left(1 - \frac{500}{T_2}\right) Q_3$$

$$\boxed{W_3 = \left(1 - \frac{500}{T_2}\right)\left[Q_1 \frac{T_2}{1000}\right]}$$

So, $\boxed{W_1 = \left(1 - \frac{T_1}{1000}\right) Q_1}$, $\boxed{W_2 = \left(1 - \frac{T_2}{T_1}\right) \frac{Q_1 T_1}{1000}}$

as $\frac{W_1}{W_2} = \frac{7}{5}$.

So, $$\frac{1 - \frac{T_1}{1000}}{\left(1 - \frac{T_2}{T_1}\right) \frac{T_1}{1000}} = \frac{7}{5}.$$

$$5 - \frac{5T_1}{1000} = 7\left[\frac{T_1}{1000} - \frac{T_2}{1000}\right]$$

$$5 = \frac{12T_1}{1000} - \frac{7T_2}{1000}.$$

$$\boxed{12T_1 - 7T_2 = 5000} \quad — (1).$$

also, $\frac{W_2}{W_3} = \frac{5}{4}$

$$\frac{\left(1 - \frac{T_2}{T_1}\right) \frac{T_1}{\cancel{1000}}}{\left(1 - \frac{500}{T_2}\right) \frac{T_2}{\cancel{1000}}} = \frac{5}{4}$$

$$\frac{T_1 - T_2}{T_2 - 500} = 5/4$$

$$4T_1 - 4T_2 = 5T_2 - 2500$$

$$\cancel{4T_1 - 9} \quad \boxed{9T_2 - 4T_1 = 2500} \quad -(ii)$$

So, $T_2 = \frac{2500 + 4T_1}{9}$, putting this in (1)

Solving ~~(1) and (2)~~,

$$\boxed{T_1 = 781.25\,k}$$

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$$\boxed{T_2 = 625\,k}$$

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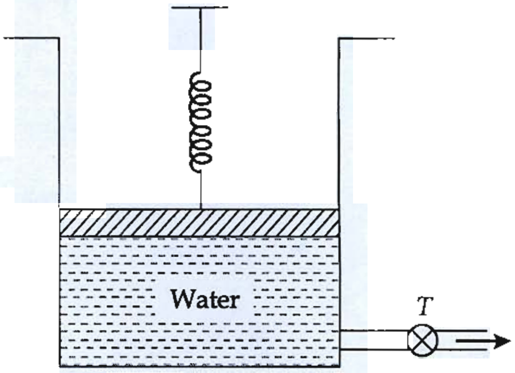
Q.3 (a) In a process industry hot gases are delivered by different units. One unit delivers a gas A at 1 bar and 1200 K at a rate of 1.5 kg/sec while a second unit delivers a gas B at 1 bar and 900 K at a rate of 2 kg/sec. These hot gases are usually cooled to 300 K in heat exchangers. The ambient atmosphere is at 300 K. An engineer plans to use the hot gases as source and ambient atmosphere as sink to operate a heat engine and thus obtain some power. Calculate the maximum power that can be obtained if gases A and B are used as separate sources, and assume both the gases A and B are ideal with $\gamma = 1.4$, $R = 0.287$ kJ/kgK, $c_p = 1.005$ kJ/kgK, $c_v = 0.717$ kJ/kgK.

[20 marks]

Q.3 (b) A cylinder containing 30 kg of saturated liquid water at 80°C has the piston restrained by a linear spring as shown in figure below.

The valve fitted near the bottom is opened to allow 10 kg of saturated liquid to flow out at 60°C. During this process, heat transfer from the surrounding is allowed and at the end of the process, the residual liquid is saturated at 40°C. The area of cross-section of the piston is 500 cm^2. Estimate the following:



(i) Final state of water,

(ii) The magnitude of heat transfer, and

(ii) the spring constant

[Refer steam table attached]

[20 marks]

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Q.3 (c) A rigid cylinder with a volume of 3.5 m^3 contains air at 200 kPa and 27°C. The heat is transferred to air from a constant temperature heat source at 1800 K and air in the cylinder is heated to 900 K. The atmosphere is at 1 bar and 17°C. Calculate the initial and final availability of air, maximum useful work and irreversibility. Neglect changes in kinetic and potential energies.

(For Air take, $c_p = 1.005$ kJ/kgK, $c_v = 0.717$ kJ/kgK, $R = 0.287$ kJ/kgK)

[20 marks]

Q.4 (a) It is proposed to produce 1500 kg of ice per hour from liquid water at 0°C in summer when the ambient atmospheric temperature is 42°C. It is planned to use a heat engine to operate the refrigeration plant. Hot water at 110°C which is produced by solar heating, may be used as a source to supply energy as heat to the heat engine and the engine uses the ambient atmospheric air as sink. Calculate

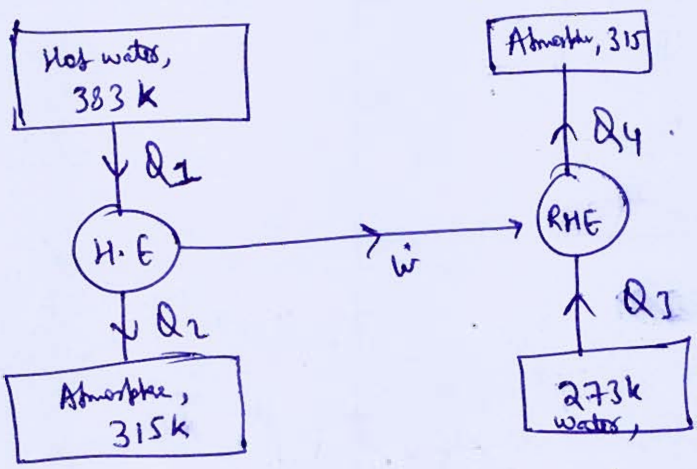
(i) the power required by the refrigeration plant

(ii) the ratio of the energy extracted as heat from the freezing water to the energy absorbed as heat by the heat engine and

(ii) the rate at which energy is rejected to the ambient atmosphere by both the devices.

The enthalpy of fusion of water at 0°C is 333.43 kJ/kg.

[20 marks]



(I) Power Required by the Refrigeration plant :-

Heat to be taken out from water at 0°C to form ice = $(m_{ice}) L_{fusion}$

$$Q_3 = \left(\frac{1500}{3600}\right)(333.43) = 138.929 \text{ kW}.$$

for a Reversible heat Engine, $(COP)_{max} = (COP)_{Carnot} = \frac{T_L}{T_H - T_L}$

$$\frac{273}{42} = \frac{\dot{Q}_3}{\dot{W}_{input}}$$

$$\dot{W}_{input} = 138.929\left(\frac{42}{273}\right) \Rightarrow \boxed{\cancel{w_{in} = 21.37 \text{ kW}}}$$

(II) $\boxed{\frac{Q_3}{Q_1} = ?}$

for Heat Engine,

$$\eta_{max} = \eta_{Carnot} = 1 - \frac{T_2}{T_1} = 1 - \frac{315}{383}$$

$$\boxed{\eta_{HE} = .1775}$$

$\therefore$, $.1775 = \frac{Q}{6} \frac{\dot{W}}{Q_1} \Rightarrow Q_1 = \frac{\dot{W}}{.1775}$.

as $\dot{W} = W_{input} \Rightarrow Q_1 = \frac{21.37}{.1775} \Rightarrow \boxed{Q_1 = 120.39 kW}$

So, $\frac{Q_3}{Q_1} = \frac{138.928}{120.39} \Rightarrow \boxed{\frac{Q_3}{Q_1} = 1.154}$

(iii) $\boxed{Q_2 + Q_4 = ?}$

$Q_2 = \dot{Q}_1 - \dot{W} = 120.39 - 21.37 = 99.02$ kW.

$Q_4 = \dot{Q}_3 + \dot{W} = 138.928 + 21.37 = 160.295$ kW

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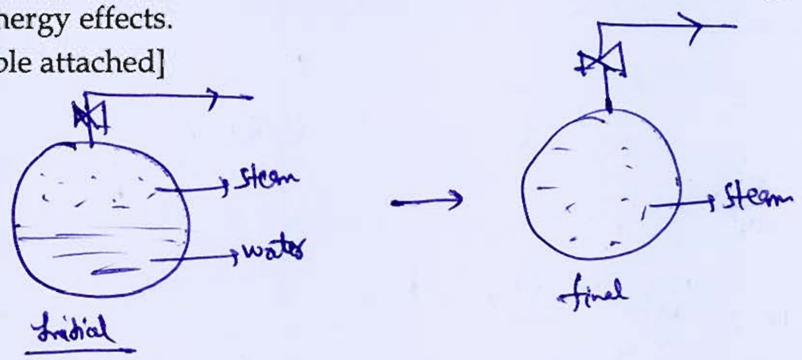
$\therefore$, $\boxed{Q_2 + Q_4 = 259.319 \text{ kW}}$

Q.4 (b) A tank having a volume of 0.95 m^3 initially contains water as a two phase liquid-vapour mixture at 300°C and a quality of 0.8. Saturated water vapour at 300°C is slowly withdrawn through a pressure regulating valve at the top of the tank as energy is transferred by heat to maintain the pressure constant in the tank. This continues until the tank is filled with saturated vapour at 300°C. Determine the amount of heat transfer. Neglect all kinetic and potential energy effects.
[Refer steam table attached]

[20 marks]



$V_{tank} = V_1 = 0.95 m^3$, $x_1 = .8$.

from steam table, at $300°C$, $v_f = .00140423\ m^3/kg$, $v_g = .021660\ m^3/kg$.

$v_1 = v_f + x v_{fg} = .00140423 + (.8)(.021660 - .00140423)$

initial specific volm, $\boxed{v_1 = .0176\ m^3/kg}$

So, let total Mass be M; so, $(M)(.0176) = V_1$

$M = \frac{0.95}{.0176} \Rightarrow$ $\boxed{\cancel{M = 5.435 kg}}$ $\boxed{M = 53.97 kg}$

also, $x = \frac{M_v}{M} \Rightarrow M_v = (.8)\ 53.970 = \cancel{4.38 kg}\ 43.17 kg$

So,

Initial Mass of steam and water in tank $\rightarrow$ $\boxed{M_{steam} = M_{v_1} = \cancel{4.38 kg}\ 43.17 kg}$

$\boxed{M_{water} = M_{l_1} = \cancel{1.095 kg}\ 10.79 kg}$

for final Condition, at $300°C$, $v_g = .021660 m^3/kg$

$M_{v_2} = \frac{V_1}{v_g} = \frac{.95}{.021660} \Rightarrow \boxed{M_{v_2} = 43.85 kg}$

By Energy Conservation

$U_1 - h_0 + Q = U_2$

U_1: initial internal energy; h_0: Enthalpy of steam taken out; U_2: final internal energy

Mass of steam taken out $= 53.97 - 43.85 = 10.12$ kg.

$u_1|_{300°C} = u_f + x\,u_{fg}$
$= 1332.9 + (.8)[2563.6 - 1332.9]$

$\boxed{u_1 = 2317.46 \text{ kJ/kg}}$

$h_o = h_g|_{300°C} \Rightarrow \boxed{h_o = 2749.6 \text{ kJ/kg}}$

$\boxed{u_2 = u_g|_{300°C} = 2563.6 \text{ kJ/kg}}$

So, $Q = (U_2 - U_1) + h_o$

$= (43.85)[2563.6] - (53.97)[2317.46]$
$+ (10.12)[2749.6]$

$\boxed{Q = 15.16 \text{ MJ}}$ → heat addition

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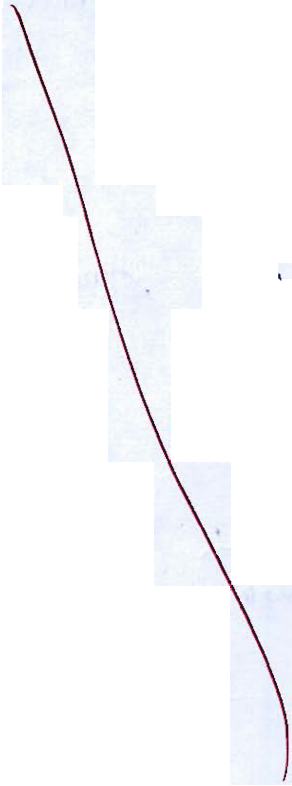
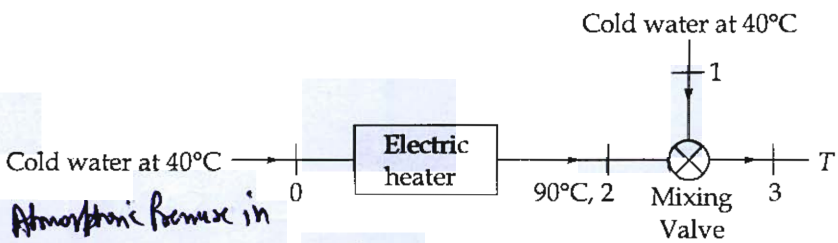
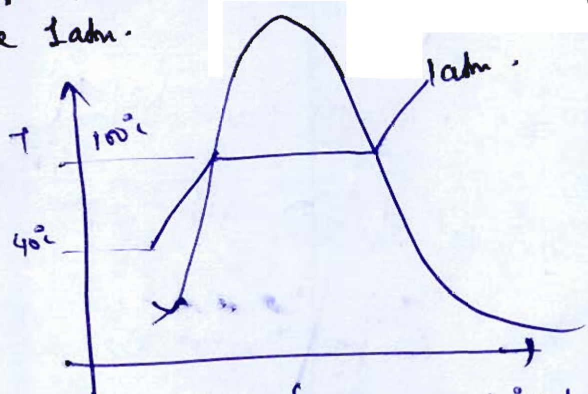


Q.4 (c) In a laboratory, hot water stream at any desired temperature T can be produced by mixing cold water at 40°C (State 1) with hot water stream leaving the electric heater at 90°C (State 2) as shown in figure. Determine the entropy generation rate for producing a hot water stream of 1.5 kg/min at 60°C (State 3) by this arrangement. Neglect the small effect of pressure on subcooled water properties.
[Refer steam table attached]



[20 marks]

Let the Atmospheric Pressure in laboratory be 1atm.



as at 1atm, ~~for~~ $T_{sat} = 100°C > 40°$ and $90°c$, both water are in Subcooled Conditions,
As it is given to neglect Effect of pressure on Subcooled water properties,

Properties of water at $40^\circ C$ = Properties of Saturated water at $40^\circ C$

from steam table

$h_0 = h_1 = 167.53$ kJ/kg.

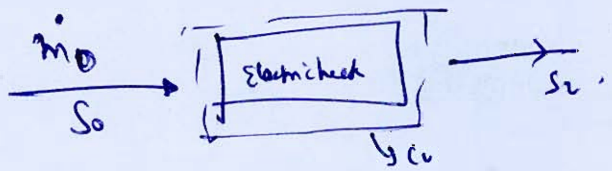
$s_0 = s_1 = .57240$ kJ/kgK.

Properties of water at $90^\circ C$ = Properties of Saturated water at $90^\circ C$.

$$\boxed{h_2 = 377.04 \text{ kJ/kg}}$$

$$\boxed{s_2 = 1.1929 \text{ kJ/kgK}}$$

for Across Electric heater, let $\dot{m}_1$ be the mass Rate of water at ⓪ Condition in Kg/min



for steady state, $S_0 + S_{gen} = S_2$

$$S_{gen}\Big|_{\text{Electric heater}} = S_{gen,1} = S_2 - S_1$$

$$= \dot{m}_0 \left[1.1929 - .57240 \right]$$

$$\boxed{S_{gen,1} = .6205\ \dot{m}_0 \text{ kJ/min K}} \quad \text{— (1)}$$

Let $\dot{m}_1$ be the mass Rate of water at Condition ①,

upon mixing, let entropy gen be $S_{gen,2}$

$$\dot{m}_1 s_1 + \dot{m}_0 s_2 + S_{gen,2} = \dot{m}_3 s_3 .$$

for S_3, ~~to~~ Properties of water = Properties of saturated water at $60^\circ C$.

$h_3 = 251.18$ kJ/kg , $S_3 = .83129$ kJ/kgK

So, $S_{gen,2} = (1.5)[.83129] - \dot{m}_1(.57240) - \dot{m}_o(1.1929)$

$$\boxed{S_{gen\,2} = 1.2469 - \dot{m}_1(.57240) - \dot{m}_o(1.1929) \text{ kJ/min K}}$$ (II)

$$\boxed{\text{Now, } \dot{m}_1 + \dot{m}_o = 1.59}$$ — (III)

also, $\dot{m}_1 h_1 + \dot{m}_o h_2 = (1.59) h_3$

$(\dot{m}_1)[167.53] + (\dot{m}_o)[377.04] = 1.59(251.18)$

$$\boxed{\dot{m}_1 + 2.25\,\dot{m}_o = 2.38}$$ (IV)

Solving (III) & (IV) $\dot{m}_1 = .95$ kg/min , $\dot{m}_o = .64$ kg/min.

So, total entropy generation $= S_{gen,1} + S_{gen\,2}$

$= .6205\,\dot{m}_o + 1.2469 - \dot{m}_1(.57240) - \dot{m}_o(1.1929)$

$= .6205(.64) + 1.2469 - .95[.57240] - .64[1.1929]$

$$\boxed{(\Delta S)_{gen} = .336 \text{ kJ/min-K}}$$ → Answer

~~$(\Delta S)_{gen} = 20.202$ kW/K~~

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Saturated Water and Steam (Temperature-based)

T °C	p_{sat} MPa	Volume, m³/kg v_f	v_g	Energy, kJ/kg u_f	u_g	Enthalpy, kJ/kg h_f	h_g	h_{fg}	Entropy, kJ/(kg K) s_f	s_g	s_{fg}
0.01	0.0006117	0.00100021	205.991	0	2374.9	0.00	2500.9	2500.9	0	9.1555	9.1555
1	0.0006571	0.00100015	192.439	4.18	2376.2	4.18	2502.7	2498.6	0.01526	9.1291	9.1138
2	0.0007060	0.00100011	179.758	8.39	2377.7	8.39	2504.6	2496.2	0.03061	9.1027	9.0720
3	0.0007581	0.00100008	168.008	12.60	2379.0	12.60	2506.4	2493.8	0.04589	9.0765	9.0306
4	0.0008135	0.00100007	157.116	16.81	2380.4	16.81	2508.2	2491.4	0.06110	9.0505	8.9894
5	0.0008726	0.00100008	147.011	21.02	2381.8	21.02	2510.1	2489.0	0.07625	9.0248	8.9486
6	0.0009354	0.00100011	137.633	25.22	2383.2	25.22	2511.9	2486.7	0.09134	8.9993	8.9080
7	0.0010021	0.00100014	128.923	29.43	2384.5	29.43	2513.7	2484.3	0.10637	8.9741	8.8677
8	0.0010730	0.00100020	120.829	33.63	2386.0	33.63	2515.6	2481.9	0.12133	8.9491	8.8278
9	0.0011483	0.00100026	113.304	37.82	2387.3	37.82	2517.4	2479.6	0.13624	8.9243	8.7881
10	0.0012282	0.00100035	106.303	42.02	2388.6	42.02	2519.2	2477.2	0.15109	8.8998	8.7487
11	0.0013130	0.00100044	99.787	46.22	2390.0	46.22	2521.0	2474.8	0.16587	8.8754	8.7096
12	0.0014028	0.00100055	93.719	50.41	2391.4	50.41	2522.9	2472.5	0.18061	8.8513	8.6707
13	0.0014981	0.00100067	88.064	54.60	2392.8	54.60	2524.7	2470.1	0.19528	8.8274	8.6321
14	0.0015990	0.00100080	82.793	58.79	2394.1	58.79	2526.5	2467.7	0.20990	8.8037	8.5938
15	0.0017058	0.00100094	77.875	62.98	2395.5	62.98	2528.3	2465.4	0.22446	8.7803	8.5558
16	0.0018188	0.00100110	73.286	67.17	2396.9	67.17	2530.2	2463.0	0.23897	8.7570	8.5180
17	0.0019384	0.00100127	69.001	71.36	2398.2	71.36	2532.0	2460.6	0.25343	8.7339	8.4805
18	0.0020647	0.00100145	64.998	75.54	2399.6	75.54	2533.8	2458.3	0.26783	8.7111	8.4433
19	0.0021983	0.00100164	61.256	79.73	2400.9	79.73	2535.6	2455.9	0.28218	8.6884	8.4063
20	0.0023393	0.00100184	57.757	83.91	2402.3	83.91	2537.4	2453.5	0.29648	8.6660	8.3695
21	0.0024882	0.00100205	54.483	88.10	2403.7	88.10	2539.3	2451.2	0.31073	8.6437	8.3330
22	0.0026453	0.00100228	51.418	92.28	2405.1	92.28	2541.1	2448.8	0.32493	8.6217	8.2967
23	0.0028111	0.00100251	48.548	96.46	2406.4	96.46	2542.9	2446.4	0.33908	8.5998	8.2607
24	0.0029858	0.00100275	45.858	100.65	2407.8	100.65	2544.7	2444.0	0.35318	8.5781	8.2250
25	0.0031699	0.00100301	43.337	104.83	2409.1	104.83	2546.5	2441.7	0.36722	8.5566	8.1894
26	0.0033639	0.00100327	40.973	109.01	2410.5	109.01	2548.3	2439.3	0.38123	8.5353	8.1541
27	0.0035681	0.00100354	38.754	113.19	2411.8	113.19	2550.1	2436.9	0.39518	8.5142	8.1191
28	0.0037831	0.00100382	36.672	117.37	2413.2	117.37	2551.9	2434.6	0.40908	8.4933	8.0842
29	0.0040092	0.00100411	34.716	121.55	2414.5	121.55	2553.7	2432.2	0.42294	8.4725	8.0496
30	0.0042470	0.00100441	32.878	125.73	2415.9	125.73	2555.5	2429.8	0.43675	8.4520	8.0152
31	0.0044969	0.00100472	31.151	129.91	2417.2	129.91	2557.3	2427.4	0.45052	8.4316	7.9810
32	0.0047596	0.00100504	29.526	134.09	2418.7	134.09	2559.2	2425.1	0.46424	8.4113	7.9471
33	0.0050354	0.00100537	27.998	138.26	2420.0	138.27	2561.0	2422.7	0.47792	8.3913	7.9134
34	0.0053251	0.00100570	26.560	142.44	2421.4	142.45	2562.8	2420.3	0.49155	8.3714	7.8799
35	0.0056290	0.00100605	25.205	146.62	2422.6	146.63	2564.5	2417.9	0.50513	8.3517	7.8466
36	0.0059479	0.00100640	23.929	150.80	2424.0	150.81	2566.3	2415.5	0.51867	8.3321	7.8135
37	0.0062823	0.00100676	22.727	154.98	2425.3	154.99	2568.1	2413.1	0.53217	8.3127	7.7806
38	0.0066328	0.00100713	21.593	159.16	2426.7	159.17	2569.9	2410.8	0.54562	8.2935	7.7479
39	0.0070002	0.00100750	20.524	163.34	2428.0	163.35	2571.7	2408.4	0.55903	8.2745	7.7154
40	0.0073849	0.00100789	19.515	167.52	2429.4	167.53	2573.5	2406.0	0.57240	8.2555	7.6831

Saturated Water and Steam (Temperature-based), Contd.

T °C	p_{sat} MPa	Volume, m³/kg v_f	v_g	Energy, kJ/kg u_f	u_g	Enthalpy, kJ/kg h_f	h_g	h_{fg}	Entropy, kJ/(kg K) s_f	s_g	s_{fg}
40	0.0073849	0.00100789	19.515	167.52	2429.4	167.53	2573.5	2406.0	0.57240	8.2555	7.6831
41	0.0077878	0.00100828	18.563	171.70	2430.7	171.71	2575.3	2403.6	0.58573	8.2368	7.6511
42	0.0082096	0.00100868	17.664	175.88	2432.1	175.89	2577.1	2401.2	0.59901	8.2182	7.6192
43	0.0086508	0.00100909	16.814	180.06	2433.1	180.07	2578.9	2398.8	0.61225	8.1998	7.5875
44	0.0091124	0.00100950	16.011	184.24	2434.7	184.25	2580.6	2396.4	0.62545	8.1815	7.5560
45	0.0095950	0.00100992	15.252	188.42	2436.1	188.43	2582.4	2394.0	0.63861	8.1633	7.5247
46	0.010099	0.00101036	14.534	192.61	2437.4	192.62	2584.2	2391.6	0.65173	8.1453	7.4936
47	0.010627	0.00101079	13.855	196.79	2438.8	196.80	2586.0	2389.2	0.66181	8.1275	7.4627
48	0.011177	0.00101124	13.212	200.97	2440.1	200.98	2587.8	2386.8	0.67785	8.1098	7.4320
49	0.011752	0.00101169	12.603	205.15	2441.4	205.16	2589.5	2384.4	0.69085	8.0922	7.4014
50	0.012352	0.00101215	12.027	209.33	2442.7	209.34	2591.3	2381.9	0.70381	8.0748	7.3710
51	0.012978	0.00101262	11.481	213.51	2444.1	213.52	2593.1	2379.5	0.71673	8.0576	7.3408
52	0.013631	0.00101309	10.963	217.70	2445.4	217.71	2594.8	2377.1	0.72961	8.0404	7.3108
53	0.014312	0.00101357	10.472	221.88	2446.7	221.89	2596.6	2374.7	0.74245	8.0234	7.2810
54	0.015022	0.00101406	10.006	226.05	2448.0	226.07	2598.3	2372.3	0.75526	8.0066	7.2513
55	0.015762	0.00101455	9.5643	230.24	2449.3	230.26	2600.1	2369.8	0.76802	7.9898	7.2218
56	0.016533	0.00101505	9.1448	234.42	2450.6	234.44	2601.8	2367.4	0.78075	7.9732	7.1925
57	0.017336	0.00101556	8.7466	238.60	2452.0	238.62	2603.6	2365.0	0.79344	7.9568	7.1633
58	0.018171	0.00101608	8.3683	242.79	2453.2	242.81	2605.3	2362.5	0.80610	7.9404	7.1343
59	0.019041	0.00101660	8.0089	246.97	2454.6	246.99	2607.1	2360.1	0.81871	7.9242	7.1055
60	0.019946	0.00101713	7.6672	251.16	2455.9	251.18	2608.8	2357.7	0.83129	7.9081	7.0769
61	0.020888	0.00101766	7.3424	255.35	2457.2	255.37	2610.6	2355.2	0.84384	7.8922	7.0484
62	0.021867	0.00101821	7.0335	259.53	2458.5	259.55	2612.3	2352.8	0.85634	7.8764	7.0200
63	0.022885	0.00101875	6.7396	263.72	2459.8	263.74	2614.0	2350.3	0.86882	7.8607	6.9918
64	0.023943	0.00101931	6.4598	267.91	2461.1	267.93	2615.8	2347.8	0.88125	7.8451	6.9638
65	0.025042	0.00101987	6.1935	272.09	2462.4	272.12	2617.5	2345.4	0.89365	7.8296	6.9359
66	0.026183	0.00102044	5.9399	276.27	2463.7	276.30	2619.2	2342.9	0.90602	7.8142	6.9082
67	0.027368	0.00102101	5.6984	280.46	2465.0	280.49	2621.0	2340.5	0.91835	7.7990	6.8807
68	0.028599	0.00102159	5.4682	284.65	2466.3	284.68	2622.7	2338.0	0.93061	7.7839	6.8532
69	0.029876	0.00102218	5.2488	288.84	2467.6	288.87	2624.4	2335.5	0.94291	7.7689	6.8260
70	0.031201	0.00102277	5.0395	293.04	2468.9	293.07	2626.1	2333.0	0.95513	7.7540	6.7989
71	0.032575	0.00102337	4.8100	297.23	2470.1	297.26	2627.8	2330.5	0.96733	7.7392	6.7719
72	0.034000	0.00102398	4.6196	301.42	2471.4	301.45	2629.5	2328.1	0.97949	7.7246	6.7451
73	0.035478	0.00102459	4.4680	305.60	2472.7	305.64	2631.2	2325.6	0.99161	7.7100	6.7184
74	0.037009	0.00102521	4.2945	309.80	2474.0	309.84	2632.9	2323.1	1.0037	7.6955	6.6918
75	0.038595	0.00102584	4.1289	313.99	2475.2	314.03	2634.6	2320.6	1.0158	7.6812	6.6654
76	0.040239	0.00102647	3.9708	318.18	2476.5	318.22	2636.3	2318.1	1.0278	7.6670	6.6392
77	0.041941	0.00102710	3.8197	322.38	2477.8	322.42	2638.0	2315.6	1.0398	7.6528	6.6130
78	0.043703	0.00102775	3.6752	326.58	2479.1	326.62	2639.7	2313.0	1.0517	7.6388	6.5871
79	0.045527	0.00102840	3.5372	330.76	2480.3	330.81	2641.3	2310.5	1.0637	7.6249	6.5612
80	0.047414	0.00102905	3.4052	334.96	2481.5	335.01	2643.0	2308.0	1.0756	7.6111	6.5355

Saturated Water and Steam (Temperature-based), Contd.

T °C	p_{sat} MPa	Volume, m³/kg v_f	v_g	Energy, kJ/kg u_f	u_g	Enthalpy, kJ/kg h_f	h_g	h_{fg}	Entropy, kJ/(kg K) s_f	s_g	s_{fg}
280	6.4166	0.00133284	0.030153	1228.3	2586.4	1236.9	2779.9	1543.0	3.0685	5.8579	2.7894
281	6.5139	0.00133602	0.029657	1233.4	2585.5	1242.1	2778.7	1536.6	3.0777	5.8506	2.7729
282	6.6124	0.00133922	0.029169	1238.5	2584.6	1247.4	2777.5	1530.1	3.0869	5.8432	2.7563
283	6.7120	0.00134247	0.028690	1243.7	2583.7	1252.7	2776.3	1523.6	3.0962	5.8358	2.7396
284	6.8128	0.00134575	0.028219	1248.7	2582.7	1257.9	2775.0	1517.1	3.1054	5.8284	2.7229
285	6.9147	0.00134907	0.027756	1253.9	2581.8	1263.2	2773.7	1510.5	3.1147	5.8209	2.7062
286	7.0177	0.00135243	0.027301	1259.1	2580.8	1268.6	2772.4	1503.8	3.1240	5.8135	2.6895
287	7.1220	0.00135584	0.026853	1264.2	2579.8	1273.9	2771.0	1497.1	3.1333	5.8060	2.6727
288	7.2274	0.00135928	0.026413	1269.5	2578.7	1279.3	2769.6	1490.4	3.1426	5.7985	2.6559
289	7.3340	0.00136277	0.025981	1274.6	2577.7	1284.6	2768.2	1483.5	3.1519	5.7909	2.6390
290	7.4418	0.00136630	0.025555	1279.8	2576.5	1290.0	2766.7	1476.7	3.1612	5.7834	2.6222
291	7.5508	0.00136987	0.025136	1285.1	2575.4	1295.4	2765.2	1469.7	3.1705	5.7758	2.6052
292	7.6610	0.00137349	0.024724	1290.4	2574.2	1300.9	2763.6	1462.7	3.1799	5.7681	2.5883
293	7.7725	0.00137716	0.024319	1295.6	2573.0	1306.3	2762.0	1455.7	3.1892	5.7605	2.5712
294	7.8852	0.00138087	0.023921	1300.9	2571.8	1311.8	2760.4	1448.6	3.1986	5.7528	2.5542
295	7.9991	0.00138464	0.023529	1306.2	2570.5	1317.3	2758.7	1441.4	3.2080	5.7451	2.5371
296	8.1143	0.00138845	0.023143	1311.5	2569.2	1322.8	2757.0	1434.2	3.2174	5.7373	2.5199
297	8.2308	0.00139231	0.022763	1316.8	2567.8	1328.3	2755.2	1426.9	3.2268	5.7295	2.5027
298	8.3485	0.00139623	0.022390	1322.1	2566.5	1333.8	2753.4	1419.5	3.2362	5.7217	2.4854
299	8.4676	0.00140020	0.022022	1327.5	2565.0	1339.4	2751.5	1412.1	3.2457	5.7138	2.4681
300	8.5879	0.00140423	0.021660	1332.9	2563.6	1345.0	2749.6	1404.6	3.2552	5.7059	2.4507
301	8.7095	0.00140831	0.021304	1338.3	2562.2	1350.6	2747.7	1397.1	3.2647	5.6979	2.4333
302	8.8325	0.00141245	0.020953	1343.8	2560.6	1356.3	2745.7	1389.4	3.2742	5.6899	2.4158
303	8.9568	0.00141665	0.020608	1349.2	2559.1	1361.9	2743.7	1381.7	3.2837	5.6819	2.3982
304	9.0824	0.00142091	0.020268	1354.7	2557.5	1367.6	2741.6	1374.0	3.2932	5.6738	2.3806
305	9.2094	0.00142524	0.019933	1360.2	2555.8	1373.3	2739.4	1366.1	3.3028	5.6657	2.3629
306	9.3378	0.00142963	0.019604	1365.7	2554.1	1379.0	2737.2	1358.2	3.3124	5.6575	2.3452
307	9.4675	0.00143408	0.019279	1371.2	2552.5	1384.8	2735.0	1350.2	3.3220	5.6493	2.3273
308	9.5986	0.00143861	0.018960	1376.8	2550.7	1390.6	2732.7	1342.1	3.3316	5.6411	2.3094
309	9.7311	0.00144320	0.018645	1382.4	2549.0	1396.4	2730.4	1334.0	3.3413	5.6327	2.2915
310	9.8651	0.00144787	0.018335	1387.9	2547.0	1402.2	2727.9	1325.7	3.3510	5.6244	2.2734
311	10.000	0.00145261	0.018029	1393.6	2545.2	1408.1	2725.5	1317.4	3.3607	5.6159	2.2553
312	10.137	0.00145743	0.017728	1399.2	2543.3	1414.0	2723.0	1309.0	3.3704	5.6074	2.2370
313	10.275	0.00146232	0.017431	1404.9	2541.3	1419.9	2720.4	1300.5	3.3802	5.5989	2.2187
314	10.415	0.00146730	0.017139	1410.5	2539.3	1425.8	2717.8	1291.9	3.3900	5.5903	2.2003
315	10.556	0.00147236	0.016851	1416.3	2537.2	1431.8	2715.1	1283.2	3.3998	5.5816	2.1818
316	10.699	0.00147751	0.016567	1422.0	2535.0	1437.8	2712.3	1274.5	3.4097	5.5729	2.1632
317	10.843	0.00148275	0.016287	1427.8	2532.9	1443.9	2709.5	1265.6	3.4195	5.5641	2.1445
318	10.989	0.00148809	0.016011	1433.6	2530.7	1450.0	2706.6	1256.6	3.4295	5.5552	2.1257
319	11.136	0.00149351	0.015739	1439.5	2528.3	1456.1	2703.6	1247.5	3.4394	5.5462	2.1068
320	11.284	0.00149901	0.015471	1445.3	2526.0	1462.2	2700.6	1238.4	3.4491	5.5372	2.0878

Saturated Water and Steam (Temperature-based), Contd.

T °C	p_{sat} MPa	Volume, m³/kg v_f	v_g	Energy, kJ/kg u_f	u_g	Enthalpy, kJ/kg h_f	h_g	h_{fg}	Entropy, kJ/(kg K) s_f	s_g	s_{fg}
80	0.047414	0.00102905	3.4052	334.96	2481.5	335.01	2643.0	2308.0	1.0756	7.6111	6.5355
81	0.049367	0.00102972	3.2789	339.16	2482.8	339.21	2644.7	2305.5	1.0874	7.5973	6.5099
82	0.051387	0.00103038	3.1581	343.36	2484.1	343.41	2646.4	2302.9	1.0993	7.5837	6.4844
83	0.053476	0.00103106	3.0125	347.55	2485.3	347.61	2648.0	2300.4	1.1111	7.5702	6.4591
84	0.055635	0.00103174	2.9318	351.75	2486.6	351.81	2649.7	2297.9	1.1229	7.5567	6.4339
85	0.057867	0.00103243	2.8258	355.95	2487.8	356.01	2651.3	2295.3	1.1346	7.5434	6.4088
86	0.060173	0.00103312	2.7244	360.16	2489.1	360.22	2653.0	2292.8	1.1463	7.5302	6.3838
87	0.062556	0.00103382	2.6271	364.36	2490.3	364.42	2654.6	2290.2	1.1580	7.5170	6.3590
88	0.065017	0.00103452	2.5340	368.56	2491.5	368.63	2656.3	2287.6	1.1696	7.5040	6.3343
89	0.067558	0.00103524	2.4447	372.76	2492.7	372.83	2657.9	2285.1	1.1813	7.4910	6.3097
90	0.070182	0.00103595	2.3591	376.97	2493.9	377.04	2659.5	2282.5	1.1929	7.4781	6.2853
91	0.072890	0.00103668	2.2770	381.17	2495.2	381.25	2661.2	2279.9	1.2044	7.4653	6.2609
92	0.075684	0.00103741	2.1982	385.38	2496.4	385.46	2662.8	2277.3	1.2160	7.4526	6.2367
93	0.078568	0.00103814	2.1227	389.59	2497.6	389.67	2664.4	2274.7	1.2275	7.4400	6.2126
94	0.081541	0.00103888	2.0502	393.80	2498.8	393.88	2666.0	2272.1	1.2389	7.4275	6.1886
95	0.084608	0.00103963	1.9806	398.00	2500.0	398.09	2667.6	2269.5	1.2504	7.4151	6.1647
96	0.087771	0.00104038	1.9137	402.21	2501.2	402.30	2669.2	2266.9	1.2618	7.4027	6.1409
97	0.091030	0.00104114	1.8496	406.43	2502.4	406.52	2670.8	2264.3	1.2732	7.3904	6.1172
98	0.094390	0.00104191	1.7879	410.63	2503.6	410.73	2672.4	2261.7	1.2846	7.3783	6.0937
99	0.097852	0.00104268	1.7287	414.85	2504.8	414.95	2674.0	2259.0	1.2959	7.3661	6.0702
100	0.10142	0.00104346	1.6718	419.06	2506.0	419.17	2675.6	2256.4	1.3072	7.3541	6.0469
101	0.10509	0.00104425	1.6171	423.28	2507.2	423.39	2677.1	2253.8	1.3185	7.3422	6.0237
102	0.10887	0.00104504	1.5644	427.50	2508.4	427.61	2678.7	2251.1	1.3297	7.3303	6.0006
103	0.11277	0.00104583	1.5139	431.71	2509.6	431.83	2680.3	2248.5	1.3410	7.3185	5.9775
104	0.11678	0.00104664	1.4652	435.93	2510.7	436.05	2681.8	2245.8	1.3522	7.3068	5.9546
105	0.12090	0.00104744	1.4184	440.14	2511.9	440.27	2683.4	2243.1	1.3633	7.2952	5.9318
106	0.12515	0.00104826	1.3733	444.37	2513.0	444.50	2684.9	2240.4	1.3745	7.2836	5.9091
107	0.12952	0.00104908	1.3300	448.59	2514.2	448.73	2686.5	2237.7	1.3856	7.2721	5.8865
108	0.13401	0.00104991	1.2882	452.81	2515.4	452.95	2688.0	2235.1	1.3967	7.2607	5.8640
109	0.13863	0.00105074	1.2480	457.03	2516.5	457.18	2689.5	2232.4	1.4078	7.2493	5.8416
110	0.14338	0.00105158	1.2093	461.27	2517.7	461.42	2691.1	2229.6	1.4188	7.2381	5.8193
111	0.14826	0.00105243	1.1720	465.49	2518.8	465.65	2692.6	2226.9	1.4298	7.2269	5.7970
112	0.15328	0.00105328	1.1361	469.72	2520.0	469.88	2694.1	2224.2	1.4408	7.2157	5.7749
113	0.15844	0.00105414	1.1014	473.95	2521.1	474.12	2695.6	2221.5	1.4518	7.2047	5.7529
114	0.16374	0.00105500	1.0680	478.18	2522.2	478.35	2697.1	2218.7	1.4628	7.1937	5.7309
115	0.16918	0.00105588	1.0358	482.41	2523.4	482.59	2698.6	2216.0	1.4737	7.1828	5.7091
116	0.17477	0.00105675	0.99522	486.65	2526.2	486.83	2700.1	2213.2	1.4846	7.1719	5.6873
117	0.18052	0.00105764	0.97486	490.89	2525.5	491.08	2701.5	2210.5	1.4954	7.1611	5.6657
118	0.18641	0.00105853	0.94598	495.12	2526.7	495.32	2703.0	2207.7	1.5063	7.1504	5.6441
119	0.19246	0.00105942	0.91811	499.36	2527.8	499.56	2704.5	2204.9	1.5171	7.1397	5.6226
120	0.19867	0.00106033	0.89121	503.60	2528.8	503.81	2705.9	2202.1	1.5279	7.1291	5.6012

Saturated Water and Steam (Pressure-based), Contd.

p MPa	T_{sat} °C	Volume, m³/kg v_f	v_g	Energy, kJ/kg u_f	u_g	Enthalpy, kJ/kg h_f	h_g	h_{fg}	Entropy, kJ/(kg K) s_f	s_g	s_{fg}
0.050	81.317	0.00102993	3.2400	340.49	2483.2	340.54	2645.2	2304.7	1.0912	7.5930	6.5018
0.055	83.709	0.00103154	2.9635	350.53	2486.2	350.59	2649.2	2298.6	1.1194	7.5606	6.4412
0.060	85.926	0.00103307	2.7317	359.85	2489.0	359.91	2652.9	2292.9	1.1454	7.5311	6.3857
0.065	87.993	0.00103452	2.5346	368.53	2491.6	368.60	2656.3	2287.7	1.1696	7.5040	6.3345
0.070	89.932	0.00103590	2.3648	376.68	2493.9	376.75	2659.4	2282.7	1.1921	7.4790	6.2869
0.075	91.758	0.00103723	2.2170	384.36	2496.1	384.44	2662.4	2277.9	1.2132	7.4557	6.2425
0.080	93.486	0.00103850	2.0871	391.63	2498.2	391.71	2665.2	2273.5	1.2330	7.4339	6.2009
0.085	95.125	0.00103972	1.9720	398.53	2500.2	398.62	2667.8	2269.2	1.2518	7.4135	6.1617
0.090	96.687	0.00104091	1.8694	405.11	2502.1	405.20	2670.3	2265.1	1.2696	7.3943	6.1246
0.095	98.178	0.00104205	1.7772	411.38	2503.9	411.48	2672.7	2261.2	1.2866	7.3761	6.0895
0.10	99.606	0.00104315	1.6939	417.40	2505.5	417.50	2674.9	2257.4	1.3028	7.3588	6.0561
0.11	102.292	0.00104527	1.5495	428.73	2508.8	428.84	2679.2	2250.3	1.3330	7.3269	5.9938
0.12	104.784	0.00104727	1.4284	439.23	2511.7	439.36	2683.1	2243.7	1.3609	7.2977	5.9367
0.13	107.109	0.00104917	1.3253	449.05	2514.3	449.19	2686.6	2237.5	1.3868	7.2709	5.8840
0.14	109.292	0.00105099	1.2366	458.27	2516.9	458.42	2690.0	2231.6	1.4110	7.2461	5.8351
0.15	111.349	0.00105273	1.1593	466.97	2519.2	467.13	2693.1	2226.0	1.4337	7.2230	5.7893
0.16	113.297	0.00105440	1.0914	475.21	2521.4	475.38	2696.0	2220.7	1.4551	7.2014	5.7463
0.17	115.148	0.00105600	1.0312	483.04	2523.5	483.22	2698.8	2215.6	1.4753	7.1812	5.7059
0.18	116.911	0.00105756	0.97747	490.51	2525.5	490.70	2701.4	2210.7	1.4945	7.1621	5.6676
0.19	118.596	0.00105906	0.92924	497.65	2527.3	497.85	2703.9	2206.0	1.5127	7.1440	5.6313
0.20	120.210	0.00106052	0.88568	504.49	2529.1	504.70	2706.2	2201.5	1.5302	7.1269	5.5967
0.21	121.759	0.00106193	0.84614	511.07	2530.8	511.29	2708.5	2197.2	1.5469	7.1106	5.5638
0.22	123.250	0.00106330	0.81007	517.40	2532.4	517.63	2710.6	2193.0	1.5628	7.0951	5.5323
0.23	124.686	0.00106464	0.77704	523.50	2534.0	523.74	2712.7	2188.9	1.5782	7.0803	5.5021
0.24	126.072	0.00106594	0.74668	529.38	2535.4	529.64	2714.6	2185.0	1.5930	7.0661	5.4731
0.25	127.411	0.00106722	0.71866	535.07	2536.8	535.34	2716.5	2181.1	1.6072	7.0524	5.4452
0.26	128.708	0.00106846	0.69273	540.59	2538.2	540.87	2718.3	2177.4	1.6210	7.0394	5.4184
0.27	129.965	0.00106968	0.66865	545.95	2539.5	546.24	2720.0	2173.8	1.6343	7.0268	5.3925
0.28	131.185	0.00107086	0.64624	551.14	2540.8	551.44	2721.7	2170.3	1.6471	7.0146	5.3675
0.29	132.370	0.00107203	0.62533	556.19	2542.0	556.50	2723.3	2166.8	1.6596	7.0029	5.3433
0.30	133.522	0.00107317	0.60576	561.11	2543.2	561.43	2724.9	2163.5	1.6717	6.9916	5.3199
0.31	134.644	0.00107429	0.58741	565.89	2544.3	566.22	2726.4	2160.2	1.6835	6.9807	5.2972
0.32	135.737	0.00107539	0.57017	570.56	2545.3	570.90	2727.8	2157.0	1.6949	6.9701	5.2752
0.33	136.802	0.00107647	0.55395	575.10	2546.5	575.46	2729.3	2153.8	1.7060	6.9598	5.2538
0.34	137.842	0.00107753	0.53864	579.54	2547.5	579.91	2730.6	2150.7	1.7168	6.9498	5.2330
0.35	138.857	0.00107857	0.52418	583.88	2548.5	584.26	2732.0	2147.7	1.7274	6.9401	5.2128
0.36	139.849	0.00107960	0.51050	588.13	2549.4	588.52	2733.2	2144.7	1.7377	6.9307	5.1931
0.37	140.819	0.00108061	0.49753	592.28	2550.4	592.68	2734.5	2141.8	1.7477	6.9216	5.1739
0.38	141.769	0.00108161	0.48522	596.34	2551.3	596.75	2735.7	2139.0	1.7575	6.9126	5.1551
0.39	142.698	0.00108259	0.47352	600.32	2552.2	600.71	2736.9	2136.2	1.7671	6.9040	5.1369
0.40	143.608	0.00108355	0.46238	604.22	2553.1	604.65	2738.1	2133.4	1.7765	6.8955	5.1190

Saturated Water and Steam (Pressure-based), Contd.

p MPa	T_{sat} °C	Volume, m³/kg v_f	v_g	Energy, kJ/kg u_f	u_g	Enthalpy, kJ/kg h_f	h_g	h_{fg}	Entropy, kJ/(kg K) s_f	s_g	s_{fg}
0.40	143.608	0.00108355	0.46238	604.22	2553.1	604.65	2738.1	2133.4	1.7765	6.8955	5.1190
0.42	145.375	0.00108541	0.44165	611.79	2554.8	612.25	2740.3	2128.0	1.7946	6.8791	5.0846
0.44	147.076	0.00108720	0.42274	619.10	2556.4	619.58	2742.4	2122.8	1.8120	6.8636	5.0516
0.46	148.716	0.00108908	0.40542	626.14	2557.9	626.64	2744.4	2117.7	1.8287	6.8487	5.0199
0.48	150.300	0.00109081	0.38950	632.95	2559.3	633.47	2746.3	2112.8	1.8448	6.8344	4.9895
0.50	151.831	0.00109255	0.37481	639.54	2560.7	640.09	2748.1	2108.0	1.8604	6.8207	4.9603
0.52	153.314	0.00109423	0.36120	645.93	2562.1	646.50	2749.9	2103.4	1.8754	6.8075	4.9321
0.54	154.753	0.00109587	0.34858	652.13	2563.3	652.72	2751.5	2098.8	1.8899	6.7948	4.9049
0.56	156.149	0.00109748	0.33682	658.16	2564.5	658.77	2753.1	2094.4	1.9040	6.7825	4.8786
0.58	157.506	0.00109905	0.32585	664.01	2565.7	664.65	2754.7	2090.0	1.9176	6.7707	4.8531
0.60	158.826	0.00110060	0.31558	669.72	2566.8	670.38	2756.1	2085.8	1.9308	6.7592	4.8284
0.62	160.112	0.00110212	0.30596	675.28	2567.9	675.96	2757.6	2081.6	1.9437	6.7482	4.8045
0.64	161.365	0.00110362	0.29691	680.70	2568.9	681.41	2758.9	2077.5	1.9562	6.7374	4.7813
0.66	162.587	0.00110509	0.28840	686.00	2570.0	686.73	2760.3	2073.5	1.9684	6.7270	4.7587
0.68	163.781	0.00110654	0.28036	691.17	2570.9	691.92	2761.5	2069.6	1.9802	6.7169	4.7367
0.70	164.946	0.00110796	0.27277	696.22	2571.9	697.00	2762.8	2065.8	1.9918	6.7071	4.7153
0.72	166.086	0.00110936	0.26559	701.17	2572.7	701.97	2763.9	2062.0	2.0031	6.6975	4.6944
0.74	167.200	0.00111075	0.25879	706.02	2573.6	706.84	2765.1	2058.2	2.0141	6.6882	4.6741
0.76	168.291	0.00111211	0.25233	710.76	2574.4	711.61	2766.2	2054.6	2.0248	6.6791	4.6543
0.78	169.360	0.00111346	0.24618	715.41	2575.3	716.28	2767.3	2051.0	2.0354	6.6703	4.6349
0.80	170.406	0.00111478	0.24034	719.97	2576.0	720.86	2768.3	2047.4	2.0457	6.6616	4.6160
0.82	171.433	0.00111609	0.23477	724.44	2576.8	725.36	2769.3	2043.9	2.0557	6.6532	4.5975
0.84	172.440	0.00111739	0.22946	728.84	2577.6	729.78	2770.3	2040.5	2.0656	6.6449	4.5793
0.86	173.428	0.00111867	0.22438	733.15	2578.2	734.11	2771.2	2037.1	2.0753	6.6369	4.5616
0.88	174.398	0.00111993	0.21953	737.38	2578.9	738.37	2772.1	2033.8	2.0847	6.6290	4.5443
0.90	175.350	0.00112118	0.21489	741.55	2579.6	742.56	2773.0	2030.5	2.0940	6.6213	4.5272
0.92	176.287	0.00112242	0.21044	745.65	2580.3	746.68	2773.9	2027.2	2.1032	6.6137	4.5106
0.94	177.207	0.00112364	0.20617	749.67	2580.9	750.73	2774.7	2024.0	2.1121	6.6063	4.4942
0.96	178.112	0.00112485	0.20208	753.64	2581.5	754.72	2775.5	2020.8	2.1209	6.5991	4.4782
0.98	179.002	0.00112605	0.19814	757.55	2582.1	758.65	2776.3	2017.7	2.1296	6.5920	4.4624
1.00	179.878	0.00112723	0.19436	761.39	2582.7	762.52	2777.1	2014.6	2.1381	6.5850	4.4470
1.05	182.009	0.00113014	0.18552	770.75	2584.1	771.94	2778.9	2007.0	2.1587	6.5681	4.4095
1.10	184.062	0.00113299	0.17745	779.78	2585.4	781.03	2780.6	1999.6	2.1785	6.5520	4.3735
1.15	186.043	0.00113577	0.17006	788.51	2586.6	789.82	2782.2	1992.4	2.1976	6.5365	4.3390
1.20	187.957	0.00113850	0.16326	796.96	2587.8	798.33	2783.7	1985.4	2.2159	6.5217	4.3058
1.25	189.809	0.00114118	0.15699	805.15	2588.9	806.58	2785.1	1978.6	2.2337	6.5074	4.2737
1.30	191.605	0.00114380	0.15119	813.11	2590.0	814.60	2786.5	1971.9	2.2508	6.4936	4.2428
1.35	193.347	0.00114638	0.14580	820.84	2590.9	822.39	2787.7	1965.3	2.2674	6.4803	4.2129
1.40	195.039	0.00114892	0.14078	828.36	2591.7	829.97	2788.8	1958.9	2.2835	6.4675	4.1839
1.45	196.685	0.00115141	0.13609	835.68	2592.6	837.35	2789.9	1952.6	2.2992	6.4550	4.1559
1.50	198.287	0.00115387	0.13171	842.83	2593.4	844.56	2791.0	1946.4	2.3143	6.4430	4.1286

Water/Steam at $p = 0.10$ MPa ($T_{sat} = 99.606$°C)

T	v	u	h	s	T	v	u	h	s
°C	m^3/kg	kJ/kg	kJ/kg	kJ/kg K	°C	m^3/kg	kJ/kg	kJ/kg	kJ/kg K
*0	0.00100016	-0.04	0.06	-0.00015	270	2.4993	2764.5	3014.4	8.1094
5	0.00100003	21.02	21.12	0.07625	280	2.5459	2779.8	3034.4	8.1459
10	0.00100030	42.02	42.12	0.15108	290	2.5924	2795.2	3054.4	8.1818
15	0.00100090	62.98	63.08	0.22445	300	2.6388	2810.6	3074.5	8.2172
20	0.00100180	83.91	84.01	0.29646	310	2.6853	2826.2	3094.7	8.2520
25	0.00100296	104.82	104.92	0.36720	320	2.7317	2841.7	3114.9	8.2864
30	0.00100437	125.72	125.82	0.43673	330	2.7782	2857.3	3135.1	8.3202
35	0.00100600	146.62	146.72	0.50510	340	2.8246	2873.0	3155.5	8.3536
40	0.00100785	167.52	167.62	0.57237	350	2.8710	2888.7	3175.8	8.3866
45	0.00100988	188.41	188.51	0.63858	360	2.9173	2904.6	3196.3	8.4191
50	0.00101211	209.32	209.42	0.70377	370	2.9637	2920.3	3216.7	8.4512
55	0.00101452	230.23	230.33	0.76798	380	3.0100	2936.3	3237.3	8.4829
60	0.00101709	251.15	251.25	0.83125	390	3.0564	2952.3	3257.9	8.5142
65	0.00101984	272.08	272.18	0.89361	400	3.1027	2968.3	3278.6	8.5452
70	0.00102274	293.02	293.12	0.95509	410	3.1490	2984.4	3299.3	8.5757
75	0.00102581	313.98	314.08	1.0157	420	3.1953	3000.6	3320.1	8.6059
80	0.00102903	334.95	335.05	1.0755	430	3.2416	3016.7	3340.9	8.6358
85	0.00103241	355.95	356.05	1.1346	440	3.2879	3033.1	3361.9	8.6653
90	0.00103594	376.96	377.06	1.1928	450	3.3342	3049.4	3382.8	8.6946
95	0.00103962	398.00	398.10	1.2504	460	3.3805	3065.8	3403.9	8.7235
99.606	0.00104315	417.40	417.50	1.3028	470	3.4267	3082.3	3425.0	8.7521
99.606	1.6939	2505.5	2674.9	7.3588	480	3.4730	3098.9	3446.2	8.7804
100	1.6959	2506.2	2675.8	7.3610	490	3.5193	3115.5	3467.4	8.8084
105	1.7204	2514.1	2686.1	7.3885	500	3.5655	3132.1	3488.7	8.8361
110	1.7447	2521.8	2696.3	7.4155	520	3.6580	3165.8	3531.6	8.8908
115	1.7690	2529.6	2706.5	7.4418	540	3.7505	3199.6	3574.7	8.9145
120	1.7932	2537.3	2716.6	7.4678	560	3.8430	3233.7	3618.0	8.9972
125	1.8172	2545.0	2726.7	7.4932	580	3.9354	3268.2	3661.7	9.0489
130	1.8412	2552.6	2736.7	7.5183	600	4.0279	3302.8	3705.6	9.0998
135	1.8652	2560.2	2746.7	7.5429	620	4.1203	3337.8	3749.8	9.1499
140	1.8891	2567.8	2756.7	7.5672	640	4.2127	3373.0	3794.3	9.1991
145	1.9129	2575.4	2766.7	7.5911	660	4.3052	3408.5	3839.0	9.2476
150	1.9367	2582.9	2776.6	7.6148	680	4.3976	3444.2	3884.0	9.2954
155	1.9604	2590.5	2786.5	7.6380	700	4.4900	3480.4	3929.4	9.3424
160	1.9841	2598.0	2796.4	7.6610	720	4.5824	3516.8	3975.0	9.3888
165	2.0077	2605.5	2806.3	7.6838	740	4.6747	3553.4	4020.9	9.4345
170	2.0313	2613.1	2816.2	7.7062	760	4.7671	3590.3	4067.0	9.4797
175	2.0549	2620.6	2826.1	7.7284	780	4.8595	3627.6	4113.5	9.5242
180	2.0785	2628.1	2836.0	7.7503	800	4.9519	3665.0	4160.2	9.5681
185	2.1020	2635.6	2845.8	7.7719	820	5.0443	3702.8	4207.2	9.6115
190	2.1255	2643.1	2855.7	7.7934	840	5.1366	3740.8	4254.5	9.6544
195	2.1490	2650.7	2865.6	7.8146	860	5.2290	3779.2	4302.1	9.6968
200	2.1724	2658.3	2875.5	7.8356	880	5.3213	3817.8	4349.9	9.7386
210	2.2193	2673.3	2895.2	7.8769	900	5.4137	3856.6	4398.0	9.7800
220	2.2661	2688.4	2915.0	7.9174	920	5.5061	3895.8	4446.4	9.8209
230	2.3128	2703.5	2934.8	7.9572	940	5.5984	3935.2	4495.0	9.8613
240	2.3595	2718.7	2954.6	7.9962	960	5.6908	3974.8	4543.9	9.9013
250	2.4062	2733.9	2974.5	8.0346	980	5.7831	4014.8	4593.1	9.9408
260	2.4528	2749.1	2994.4	8.0723	1000	5.8754	4055.1	4642.6	9.9800
270	2.4993	2764.5	3014.4	8.1094					

Saturated Water and Steam (Pressure-based), Contd.

p	T_{sat}	Volume, m^3/kg		Energy, kJ/kg		Enthalpy, kJ/kg			Entropy, kJ/(kg K)		
MPa	°C	v_f	v_g	u_f	u_g	h_f	h_g	h_{fg}	s_f	s_g	s_{fg}
1.50	198.287	0.00115387	0.13171	842.83	2593.4	844.56	2791.0	1946.4	2.3143	6.4430	4.1286
1.55	199.848	0.00115629	0.12760	849.80	2594.1	851.59	2791.9	1940.3	2.3291	6.4313	4.1022
1.60	201.370	0.00115868	0.12374	856.61	2594.8	858.46	2792.8	1934.4	2.3435	6.4199	4.0765
1.65	202.856	0.00116103	0.12010	863.25	2595.5	865.17	2793.7	1928.5	2.3575	6.4089	4.0514
1.70	204.307	0.00116336	0.11667	869.76	2596.2	871.74	2794.5	1922.7	2.3711	6.3981	4.0270
1.75	205.725	0.00116565	0.11343	876.13	2596.7	878.17	2795.2	1917.0	2.3845	6.3877	4.0032
1.80	207.112	0.00116792	0.11037	882.37	2597.2	884.47	2795.9	1911.4	2.3975	6.3775	3.9800
1.85	208.469	0.00117016	0.10746	888.49	2597.8	890.65	2796.6	1905.9	2.4102	6.3675	3.9573
1.90	209.798	0.00117238	0.10470	894.48	2598.3	896.71	2797.2	1900.5	2.4227	6.3578	3.9351
1.95	211.101	0.00117458	0.10208	900.37	2598.7	902.66	2797.8	1895.1	2.4348	6.3483	3.9135
2.0	212.377	0.00117675	0.099585	906.15	2599.1	908.50	2798.3	1889.8	2.4468	6.3390	3.8923
2.1	214.858	0.00118103	0.094938	917.39	2599.9	919.87	2799.3	1879.4	2.4699	6.3210	3.8511
2.2	217.249	0.00118523	0.090698	928.26	2600.6	930.87	2800.1	1869.2	2.4921	6.3038	3.8116
2.3	219.557	0.00118936	0.086815	938.79	2601.1	941.53	2800.8	1859.3	2.5136	6.2872	3.7736
2.4	221.789	0.00119343	0.083244	949.01	2601.6	951.87	2801.4	1849.6	2.5343	6.2712	3.7369
2.5	223.950	0.00119743	0.079949	958.92	2602.0	961.91	2801.9	1840.0	2.5543	6.2558	3.7015
2.6	226.046	0.00120138	0.076899	968.55	2602.4	971.67	2802.3	1830.7	2.5736	6.2409	3.6672
2.7	228.080	0.00120528	0.074066	977.93	2602.7	981.18	2802.7	1821.5	2.5924	6.2264	3.6340
2.8	230.057	0.00120913	0.071429	987.07	2602.9	990.46	2802.9	1812.4	2.6106	6.2124	3.6018
2.9	231.980	0.00121293	0.068968	995.99	2603.1	999.51	2803.1	1803.6	2.6283	6.1988	3.5705
3.0	233.853	0.00121669	0.066664	1004.6	2603.2	1008.3	2803.2	1794.8	2.6455	6.1856	3.5400
3.1	235.679	0.00122042	0.064504	1013.2	2603.2	1017.0	2803.2	1786.2	2.6623	6.1727	3.5104
3.2	237.459	0.00122410	0.062475	1021.5	2603.2	1025.4	2803.1	1777.7	2.6787	6.1602	3.4815
3.3	239.198	0.00122776	0.060564	1029.6	2603.1	1033.7	2803.0	1769.3	2.6946	6.1479	3.4533
3.4	240.897	0.00123138	0.058761	1037.6	2603.1	1041.8	2802.9	1761.0	2.7102	6.1360	3.4258
3.5	242.557	0.00123497	0.057058	1045.5	2602.9	1049.8	2802.6	1752.8	2.7254	6.1243	3.3989
3.6	244.182	0.00123854	0.055446	1053.1	2602.8	1057.6	2802.4	1744.8	2.7403	6.1129	3.3726
3.7	245.772	0.00124208	0.053918	1060.7	2602.6	1065.3	2802.1	1736.8	2.7549	6.1018	3.3469
3.8	247.330	0.00124559	0.052467	1068.1	2602.3	1072.8	2801.7	1728.9	2.7691	6.0908	3.3217
3.9	248.857	0.00124908	0.051089	1075.3	2602.1	1080.2	2801.3	1721.1	2.7831	6.0801	3.2970
4.0	250.354	0.00125256	0.049776	1082.5	2601.7	1087.5	2800.8	1713.3	2.7968	6.0696	3.2728
4.1	251.823	0.00125601	0.048525	1089.6	2601.3	1094.7	2800.3	1705.7	2.8102	6.0592	3.2491
4.2	253.264	0.00125944	0.047332	1096.4	2601.0	1101.7	2799.8	1698.1	2.8234	6.0491	3.2257
4.3	254.680	0.00126286	0.046192	1103.3	2600.6	1108.7	2799.2	1690.6	2.8363	6.0391	3.2028
4.4	256.070	0.00126626	0.045102	1109.9	2600.2	1115.5	2798.6	1683.1	2.8490	6.0293	3.1803
4.5	257.437	0.00126965	0.044059	1116.5	2599.6	1122.2	2797.9	1675.7	2.8615	6.0197	3.1582
4.6	258.780	0.00127302	0.043059	1123.0	2599.2	1128.9	2797.3	1668.4	2.8738	6.0102	3.1364
4.7	260.101	0.00127638	0.042100	1129.5	2598.6	1135.5	2796.5	1661.1	2.8859	6.0009	3.1150
4.8	261.402	0.00127973	0.041180	1135.8	2598.1	1141.9	2795.8	1653.9	2.8978	5.9917	3.0939
4.9	262.681	0.00128306	0.040296	1142.0	2597.5	1148.3	2795.0	1646.7	2.9095	5.9826	3.0731
5.0	263.941	0.00128639	0.039446	1148.2	2597.0	1154.6	2794.2	1639.6	2.9210	5.9737	3.0527

Water/Steam at $p = 4.0$ MPa ($T_{sat} = 250.354$°C)

T (°C)	v (m³/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg K)
0	0.00099819	0.03	4.02	0.00009
5	0.00099813	21.00	24.99	0.07617
10	0.00099841	41.92	45.91	0.15072
15	0.00099909	62.80	66.80	0.22385
20	0.00100001	83.67	87.67	0.29564
25	0.00100120	104.52	108.52	0.36619
30	0.00100263	125.36	129.37	0.43553
35	0.00100427	146.20	150.22	0.50374
40	0.00100612	167.05	171.07	0.57085
45	0.00100816	187.89	191.92	0.63691
50	0.00101038	208.74	212.78	0.70196
55	0.00101277	229.59	233.64	0.76604
60	0.00101534	250.46	254.52	0.82918
65	0.00101807	271.34	275.41	0.89141
70	0.00102095	292.23	296.31	0.95277
75	0.00102399	313.13	317.23	1.0133
80	0.00102719	334.05	338.16	1.0730
85	0.00103054	354.99	359.11	1.1319
90	0.00103403	375.94	380.08	1.1900
95	0.00103768	396.93	401.08	1.2475
100	0.00104148	417.93	422.10	1.3042
105	0.00104543	438.97	443.15	1.3602
110	0.00104953	460.02	464.22	1.4156
115	0.00105379	481.12	485.34	1.4703
120	0.00105820	502.26	506.49	1.5245
125	0.00106277	523.43	527.68	1.5780
130	0.00106751	544.64	548.91	1.6310
135	0.00107240	565.90	570.19	1.6835
140	0.00107747	587.22	591.53	1.7354
145	0.00108272	608.58	612.91	1.7869
150	0.00108814	630.01	634.36	1.8379
155	0.00109375	651.49	655.87	1.8884
160	0.00109956	673.05	677.45	1.9385
165	0.00110556	694.69	699.11	1.9882
170	0.00111178	716.39	720.84	2.0376
175	0.00111821	738.19	742.66	2.0865
180	0.00112487	760.07	764.57	2.1352
185	0.00113177	782.05	786.58	2.1835
190	0.00113893	804.13	808.69	2.2315
195	0.00114635	826.33	830.92	2.2792
200	0.00115405	848.65	853.27	2.3267
210	0.00117038	893.67	898.35	2.4210
220	0.00118807	939.29	944.04	2.5146
230	0.00120733	985.59	990.42	2.6077
240	0.00122842	1032.7	1037.6	2.7005
250	0.00125169	1080.8	1085.8	2.7935
250.354	0.00125256	1082.5	1087.5	2.7968
250.354	0.0497760	2601.7	2800.8	6.0696
260	0.0517770	2630.0	2837.1	6.1383
270	0.0536930	2656.4	2871.2	6.2016

T (°C)	v (m³/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg K)
270	0.0536930	2656.4	2871.2	6.2016
280	0.0554970	2680.9	2902.9	6.2595
290	0.0572170	2704.1	2933.0	6.3133
300	0.0588700	2726.2	2961.7	6.3639
310	0.0604680	2747.5	2989.4	6.4118
320	0.0620210	2768.2	3016.3	6.4576
330	0.0635360	2788.4	3042.5	6.5014
340	0.0650190	2808.0	3068.1	6.5435
350	0.0664730	2827.4	3093.3	6.5843
360	0.0679030	2846.5	3118.1	6.6238
370	0.0693110	2865.4	3142.6	6.6621
380	0.0707010	2884.0	3166.8	6.6994
390	0.0720730	2902.4	3190.7	6.7358
400	0.0734310	2920.8	3214.5	6.7714
410	0.0747760	2939.0	3238.1	6.8061
420	0.0761080	2957.1	3261.5	6.8402
430	0.0774290	2975.1	3284.8	6.8736
440	0.0787410	2993.0	3308.0	6.9064
450	0.0800430	3011.0	3331.2	6.9386
460	0.0813370	3028.9	3354.2	6.9703
470	0.0826230	3046.7	3377.2	7.0015
480	0.0839020	3064.6	3400.2	7.0321
490	0.0851750	3082.4	3423.1	7.0624
500	0.0864420	3100.2	3446.0	7.0922
520	0.0889590	3136.0	3491.8	7.1506
540	0.0914570	3171.7	3537.5	7.2075
560	0.0939380	3207.4	3583.2	7.2631
580	0.0964050	3243.4	3629.0	7.3174
600	0.0988590	3279.5	3674.9	7.3705
620	0.10130	3315.7	3720.9	7.4226
640	0.10373	3352.1	3767.0	7.4737
660	0.10616	3388.6	3813.2	7.5238
680	0.10857	3425.4	3859.7	7.5730
700	0.11098	3462.4	3906.3	7.6214
720	0.11338	3499.6	3953.1	7.6690
740	0.11577	3537.0	4000.1	7.7159
760	0.11816	3574.7	4047.3	7.7620
780	0.12054	3612.5	4094.7	7.8074
800	0.12292	3650.6	4142.3	7.8523
820	0.12530	3689.0	4190.2	7.8964
840	0.12767	3727.6	4238.3	7.9400
860	0.13003	3766.5	4286.6	7.9830
880	0.13240	3805.5	4335.1	8.0255
900	0.13476	3844.9	4383.9	8.0674
920	0.13712	3884.4	4432.9	8.1088
940	0.13947	3924.2	4482.1	8.1498
960	0.14183	3964.3	4531.6	8.1902
980	0.14418	4004.6	4581.3	8.2302
1000	0.14652	4045.1	4631.2	8.2697

Water/Steam at $p = 0.30$ MPa ($T_{sat} = 133.522$°C)

T (°C)	v (m³/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg K)
0	0.00100006	-0.04	0.26	-0.00013
5	0.00099994	21.02	21.32	0.07625
10	0.00100020	42.01	42.31	0.15106
15	0.00100081	62.97	63.27	0.22442
20	0.00100170	83.89	84.19	0.29642
25	0.00100287	104.80	105.10	0.36715
30	0.00100428	125.70	126.00	0.43666
35	0.00100591	146.60	146.90	0.50503
40	0.00100776	167.49	167.79	0.57229
45	0.00100980	188.39	188.69	0.63849
50	0.00101202	209.29	209.59	0.70368
55	0.00101443	230.20	230.50	0.76788
60	0.00101700	251.11	251.42	0.83114
65	0.00101974	272.03	272.34	0.89350
70	0.00102265	292.98	293.29	0.95497
75	0.00102571	313.93	314.24	1.0156
80	0.00102893	334.90	335.21	1.0754
85	0.00103231	355.89	356.20	1.1344
90	0.00103584	376.91	377.22	1.1927
95	0.00103952	397.94	398.25	1.2502
100	0.00104336	419.01	419.32	1.3071
105	0.00104735	440.10	440.41	1.3632
110	0.00105150	461.21	461.53	1.4187
115	0.00105580	482.37	482.69	1.4736
120	0.00106027	503.56	503.88	1.5278
125	0.00106490	524.80	525.12	1.5815
130	0.00106969	546.08	546.40	1.6346
133.522	0.00107317	561.11	561.43	1.6717
133.522	0.60576	2543.2	2724.9	6.9916
135	0.60833	2545.7	2728.2	6.9998
140	0.61697	2554.3	2739.4	7.0269
145	0.62553	2562.6	2750.3	7.0533
150	0.63401	2571.0	2761.2	7.0791
155	0.64244	2579.2	2771.9	7.1044
160	0.65081	2587.4	2782.6	7.1291
165	0.65913	2595.5	2793.2	7.1534
170	0.66742	2603.5	2803.7	7.1773
175	0.67566	2611.5	2814.2	7.2008
180	0.68387	2619.4	2824.6	7.2239
185	0.69205	2627.4	2835.0	7.2467
190	0.70020	2635.2	2845.3	7.2691
195	0.70832	2643.1	2855.6	7.2913
200	0.71642	2651.0	2865.9	7.3131
210	0.73256	2666.6	2886.4	7.3560
220	0.74862	2682.2	2906.8	7.3978
230	0.76461	2697.8	2927.2	7.4387
240	0.78055	2713.3	2947.5	7.4788
250	0.79644	2729.0	2967.9	7.5180
260	0.81229	2744.5	2988.2	7.5565
270	0.82810	2760.1	3008.5	7.5943

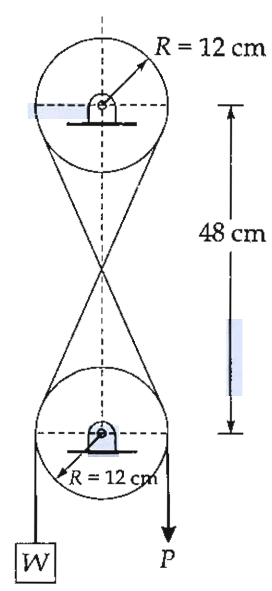
T (°C)	v (m³/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg K)
270	0.82810	2760.1	3008.5	7.5943
280	0.84388	2775.6	3028.8	7.6314
290	0.85962	2791.3	3049.2	7.6678
300	0.87534	2807.0	3069.6	7.7037
310	0.89104	2822.7	3090.0	7.7390
320	0.90672	2838.4	3110.4	7.7738
330	0.92237	2854.2	3130.9	7.8080
340	0.93801	2870.0	3151.4	7.8417
350	0.95363	2885.9	3172.0	7.8750
360	0.96924	2901.8	3192.6	7.9078
370	0.98483	2917.8	3213.2	7.9401
380	1.0004	2933.8	3233.9	7.9721
390	1.0160	2949.9	3254.7	8.0036
400	1.0315	2966.1	3275.5	8.0347
410	1.0471	2982.2	3296.3	8.0655
420	1.0626	2998.4	3317.2	8.0959
430	1.0782	3014.7	3338.2	8.1259
440	1.0937	3031.1	3359.2	8.1556
450	1.1092	3047.5	3380.3	8.1849
460	1.1247	3064.0	3401.4	8.2140
470	1.1402	3080.5	3422.6	8.2427
480	1.1557	3097.2	3443.9	8.2711
490	1.1712	3113.8	3465.2	8.2992
500	1.1867	3130.6	3486.6	8.3271
520	1.2177	3164.3	3529.6	8.3819
540	1.2486	3198.2	3572.8	8.4357
560	1.2796	3232.4	3616.3	8.4886
580	1.3105	3266.9	3660.0	8.5404
600	1.3414	3301.6	3704.0	8.5914
620	1.3723	3336.6	3748.3	8.6416
640	1.4032	3371.9	3792.9	8.6909
660	1.4341	3407.5	3837.7	8.7395
680	1.4649	3443.3	3882.8	8.7873
700	1.4958	3479.5	3928.2	8.8344
720	1.5266	3515.9	3973.9	8.8809
740	1.5575	3552.6	4019.8	8.9267
760	1.5884	3589.5	4066.0	8.9719
780	1.6192	3626.7	4112.5	9.0164
800	1.6500	3664.3	4159.3	9.0604
820	1.6809	3702.0	4206.3	9.1039
840	1.7117	3740.2	4253.7	9.1468
860	1.7425	3778.5	4301.3	9.1892
880	1.7733	3817.1	4349.1	9.2310
900	1.8042	3856.0	4397.3	9.2724
920	1.8350	3895.2	4445.7	9.3133
940	1.8658	3934.7	4494.4	9.3538
960	1.8966	3974.3	4543.3	9.3938
980	1.9274	4014.3	4592.5	9.4334
1000	1.9582	4054.5	4642.0	9.4726

Section : B

Q.5 (a) A hollow shaft of outside diameter 60 mm and inside diameter 0.4 times the outside diameter, is subjected to a torque of T(Nm) and a bending moment of 0.5T (Nm). The tensile yield stress of the shaft material is 260 MPa. For the given application, taking factor of safety to be 2, what will be the maximum permissible value of T to avoid failure according to Tresca's failure theory?

[12 marks]

Q.5 (b) A rope is looped over two fixed posts each of 24 cm diameter as shown in figure below. If the coefficient of friction $\mu = \frac{7}{8\pi}$, then determine the maximum and minimum values of P that will prevent the motion of the load $W = 7$ kN.



[12 marks]

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Q.5 (c) Two pieces of materials A and B have the same bulk modulus, but the Young's modulus of B is 2% greater than that for A. Obtain the value of modulus of rigidity for the material B in terms of Young's modulus and modulus of rigidity for material A.

[12 marks]

for material A, properties → E_1, k_1, G_1

$$\boxed{E_B = 1.02\, E_A}$$

$$\boxed{k_B = k_A}$$

Using

$$E = 3k(1-2\nu)$$

$$E_A = 3k_A(1-2\nu_A)$$

also, $E_B = 3k_B(1-2\nu_B)$

So,
$$\cancel{3k_B}\left[1-2\mu_B\right] = 1.02\ \cancel{3k_A}\left(1-2\mu_A\right)$$

$$1-2\mu_B = 1.02\left(1-2\mu_A\right)$$

$$1-2\mu_B = 1.02 - 2.04\mu_A$$

$$\cancel{2.04\mu_A}$$

$$\boxed{2.04\mu_A - 2\mu_B = .02} \quad \text{—(1)}$$

1

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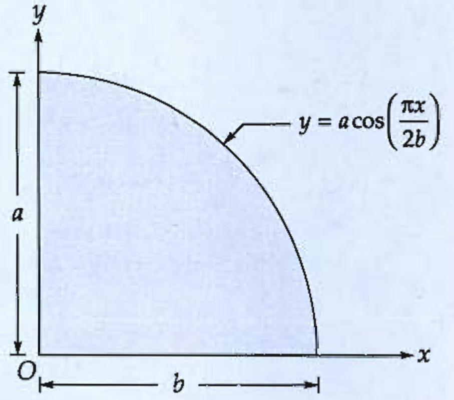
Q.5 (d) Determine the centroid of the area under the curve $y = a\cos\left(\frac{\pi x}{2b}\right)$ between $x = 0$ and $x = b$ as shown in figure below.



[12 marks]

Q.5 (e) A copper cylinder 945 mm long, 420 mm internal diameter and 10 mm thickness with flat ends, is initially full of oil at atmospheric pressure. Calculate the volume of oil which must be pumped into the cylinder in order raise the pressure to 6 MPa above atmospheric pressure. For copper, take $E = 100$ GPa and $\mu = 0.3$. Take bulk modulus of oil as 2600 MPa. Neglect the deformation of the end plates.

[12 marks]

Q.6 (a) **(i)** A seamless spherical shell is of 87.5 cm internal diameter and 6 mm thickness. It is filled with fluid under pressure until its volume increases by 64 cm^3. Calculate the fluid pressure by taking E = 205 GPa and Poisson's ratio = 0.32.

(ii) A body is under action of two principal stresses of 50 MPa and –80 MPa and the third principle stress being zero. The elastic limit in simple tension and compression is 210 MPa. Calculate the factor of safety based on the elastic limit according to

(1) Maximum shear stress theory

(2) Maximum strain energy theory

(3) Maximum shear strain energy theory

Take poisson's ratio as 0.25.

[8 + 12 marks]

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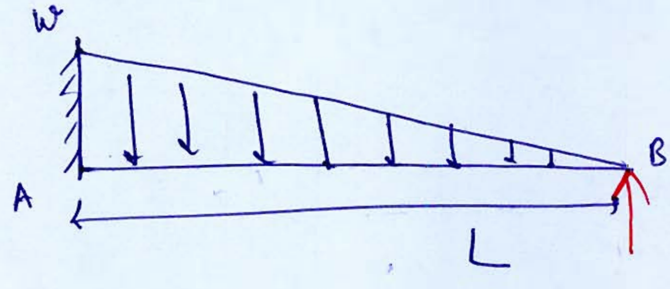
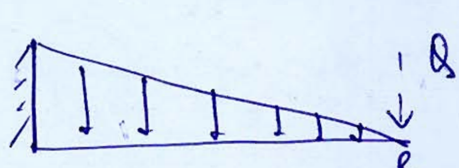
Q.6 (b) A cantilever beam of length 'L' is loaded by a uniformly varying load, the load at free end is zero and maximum load of w at the fixed end. The free end is propped to the level of fixed end. Assuming EI to be constant, calculate the reaction at prop and equation to the elastic curve along with the slope at the propped end.

[20 marks]



Calculation of Prop Reaction :-

calculating deflection at B when no prop load is used,



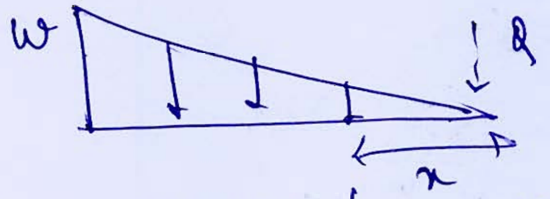
let Q be the dummy load at the free end.

~~Bending Moment at any section 'x' from B = Q~~

Using Castigliano's theorem,

$$\delta_B = \frac{1}{EI}\int_0^L M \left.\frac{\partial M}{\partial Q}\right|_{Q=0} dx.$$

At a section x from B



So, at $L \rightarrow$ intensity of loading w.

$L \rightarrow w$

$1 \rightarrow \frac{w}{L}$?

$x \rightarrow \frac{xw}{L}$.

$$\text{So, } M_x = -Qx - \left[\left(\frac{1}{2}\right)\left(\frac{wx}{L}\right)(x)\left(\frac{x}{3}\right)\right]$$

$$\frac{\partial M_x}{\partial Q} = -x$$

$$\text{So, } \delta_B = \frac{1}{EI}\int_0^L \left(-\cancel{Qx}^{\,0} - \frac{wx^3}{6L}\right)(-x)\,dx.$$

$$\delta_B = \frac{1}{EI}\int_0^L \frac{wx^4}{6L}\,dx.$$

$$\delta_B = \frac{1}{EI}\,\frac{w}{6L}\,\left.\frac{x^5}{5}\right|_0^L$$

$$\boxed{\delta_B = \frac{wL^4}{30EI}}$$

(downward)

~~So~~

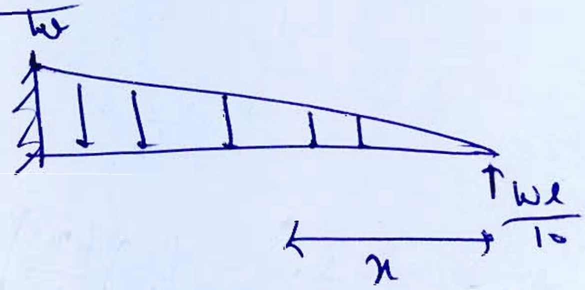
When a Prop is used, deflection caused by it at free end of Cantilever is $\frac{PL^3}{3EI}$ (upward)

So, $\frac{PL^3}{3\cancel{EI}} = \frac{wl^4}{30\cancel{EI}}$ (for No deflection at free end)

$$\boxed{P = \frac{wl}{10}}$$

Equation of Elastic curve

~~$M_x =$~~



$$M_x = \frac{wl}{10}x - \frac{wx^3}{6L}$$

So, $EI\frac{d^2y}{dx^2} = M_x$

$$\boxed{EI\frac{d^2y}{dx^2} = \frac{wl}{10}x - \frac{wx^3}{6L}}$$

8

Take time to think before proceeding for solution.

Slope at ~~free~~ Propped End

Integrating Elastic Curve Eqn,

$$EI\left(\frac{dy}{dx}\right) = \frac{wl}{10}\frac{x^2}{2} - \frac{wx^4}{24L} + C_1$$

$$\frac{dy}{dx} = \frac{1}{EI}\left[\frac{wlx^2}{20} - \frac{wx^4}{24L} + C_1\right)$$

at $x = L$, $\frac{dy}{dx} = 0 \Rightarrow 0 = \frac{wl^3}{20} - \frac{wl^3}{24} + C_1$

$$C_1 = \frac{wl^3}{24} - \frac{wl^3}{20}$$

$$C_1 = \frac{5wl^3 - 6wl^3}{120} \Rightarrow \boxed{C_1 = -\frac{wl^3}{120}}$$

So, slope at ~~the~~ Propped End, $x = 0$

$$\boxed{\left.\frac{dy}{dx}\right|_{x=0} = \frac{1}{EI}C_1 = \frac{-wl^3}{120EI}}.$$

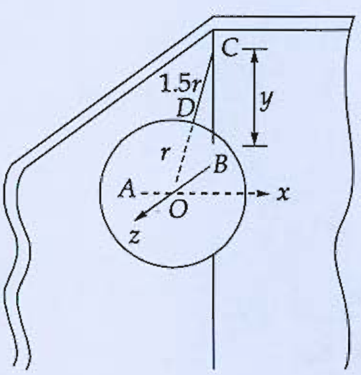
Q.6 (c) Two steel plugs fit freely into the ends of a steel tubular distance piece 420 mm long and drawn together by a steel bolt 520 mm long and nut, the nut being tight fit in the beginning. The nut is further tightened by $\frac{1}{5}$ turn to draw the pieces together, the pitch of the bolt thread being 2.5 mm. The pieces are then subjected to forces of 60 kN tending to pull them apart. The area of cross-section of the bolt is 700 mm^2 and that of the tube is 500 mm^2. Young's modulus of steel is 200 GPa. Calculate the stresses in the bolt and the tube.

[20 marks]

Q.7 (a) A hollow steel shaft 4.5 m long is to transmit 150 kW of power at 120 rpm. The total angle of twist is not to exceed 1.8° in this length and the allowable shear stress is 45 MPa. Calculate the inside and outside diameters of the shaft. Assume modulus of elasticity as 200 GPa and Poisson's ratio as 0.25.

[20 marks]

Q.7 (b) A wire length 30 cm is tied to point D on the surface of a sphere of radius 20 cm. Then the wire is tied to point C which is the intersection of two smooth walls, the walls being at right angles to each other as shown in figure below. If the weight of the sphere is 500 N, then determine the tension in the wire and the reactions from the wall. Assume all contact surface are smooth.

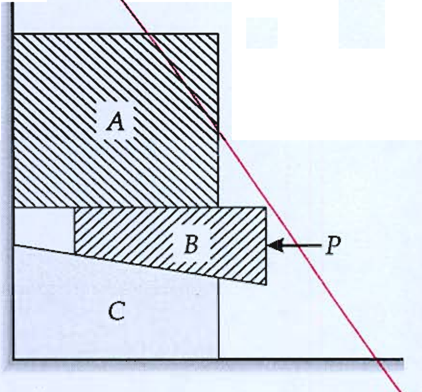


[20 marks]

Q.7 (c) The compression flange of a cast iron girder is 140 mm and 20 mm deep, the tension flange 260 mm wide and 40 mm and the web 300 mm × 20 mm. Calculate the load per metre run which may be carried over a 5 m span by a beam simply supported at the ends, if maximum permissible stresses are 95 MPa in compression and 35 MPa in tension.

[20 marks]

Q.8 (a) (i) A block 'A' weighing 840 N is raised up with the help of two 8° wedge 'B' and 'C' of negligible weights as shown in figure. If the coefficient of static friction is 0.25 for all surfaces of contact, then evaluate the smallest force P to be applied to raise the block A



(ii) A vehicle of mass 680 kg, is moving with a velocity 34 m/s. A force of 255 N acts on it for 3 minutes. Find the final velocity of the vehicle:

(1) When the force acts in the direction of motion, and

(2) When the force acts in the opposite direction of the motion.

Comment your view on final result.

[14 +6 = 20 marks]

Q.8 (b) A gun metal bar of 30 mm diameter is completely enclosed in a steel tube, 30 mm internal diameter and 45 mm external diameter. A pin, 12 mm in diameter is fitted transversely to the axis of the bar near each end, to secure the bar to the tube. Calculate the intensity of stresses induced in bar, tube and pin, when the temperature of the whole assembly is raised by 42°C.

Take : For gun metal : $\alpha_g = 20 \times 10^{-6}/°C$

$E_g = 0.91 \times 10^5 \text{ N/mm}^2$

For Steel : $\alpha_B = 12 \times 10^{-6}/°C$

$E_s = 2 \times 10^5 \text{ N/mm}^2$

[20 marks]

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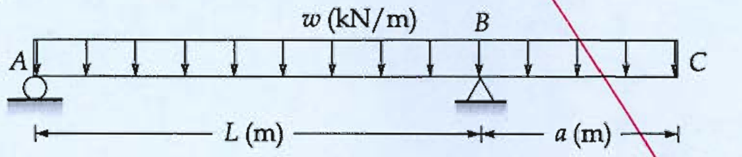
Q.8 (c) A simply supported beam with one side overhang is loaded with uniformly distributed load as shown in figure below. Comment your result on the variation of reaction forces at A and B, if 'L' is less than, equal to and greater than 'a'. Draw shear force and bending moment diagram for $w = 4$ kN/m, $L = 8$ m and $a = 4$ m.



[20 marks]

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OOOO

Space for Rough Work

Space for Rough Work

Space for Rough Work