When the wind blows over a cylindrical object - like a smoke stack or a car antenna - the flow can cause this object to oscillate. In fact, this can even be used to make a wind-driven musical stringed-instrument, called an "Aeolian Harp."

We find in practice that the frequency of an Aeolian Harp (or of a car antenna) depends upon the diameter of the antenna and the speed of the wind. Use this fact to write a non-dimensional expression for frequency as a function of wind speed V and diameter D. (3 marks)

Based on this expression, what will happen to a given harp string if the wind speed increases - does it go up in pitch or down? (2 marks)

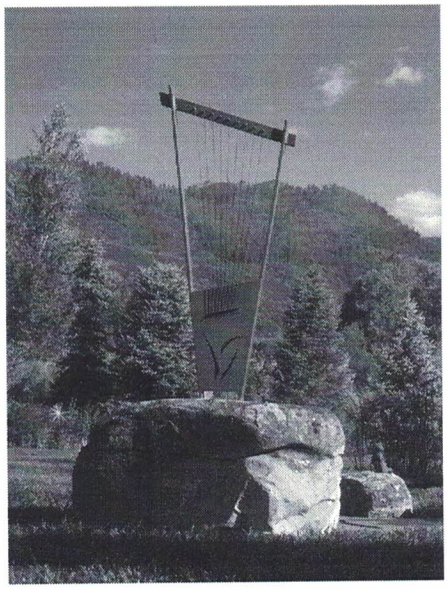


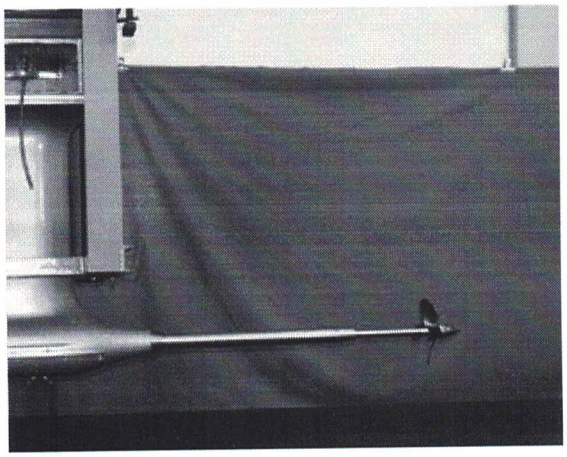
Figure 1 An Aeolian Harp

a) We need a relationship between frequency "f" $[t^{-1}]$ and diameter "d" $[L]$ and velocity "V" $[Lt^{-1}]$.

the result is the Strouhal Number:

$$\frac{f \cdot d}{V} = \frac{s \cdot m}{m \cdot s} = \pi$$

b) if we assume the strouhal number stays constant, then a higher V demands a higher f: the pitch goes up if the wind blows harder.



We wish to test a ship propeller in a water channel. The photo shows the test apparatus before placing it into the water. The propeller is characterized by its diameter "D" and its RPM "N". Our model propeller will be smaller than the full-size propeller by a factor we will call "λ," such that λ*D_model = D_prototype. We will use fresh water in the channel, although the real ship will sail in salt water (different density and viscosity). [Hint: If you get stuck, try ignoring this fact and use the same water in both cases.] We will run the water in the channel at a speed that is appropriate to simulate the ship traveling at velocity "V." In this condition the propeller generates a force "T" called "Thrust" which we use to propel the ship. We will measure this in the model test. We will also measure the torque "Q" that we have to supply to the propeller.

(2 marks) Generate a non-dimensional expression for the Thrust.

(3 marks) Generate a non-dimensional expression for the Torque.

(5 marks) At what speed do we need to run the water channel?

(7 marks) At what RPM do we need to run the model propeller?

(5 marks) For a λ–scale propeller, how much thrust should I expect (as a percentage of the full-scale thrust)?

(5 marks) For a λ–scale propeller, how much torque should I expect (as a percentage of the full-scale torque)?

(3 marks) Does this test seem practical to you? If not, why not?

a) THRUST IS A FORCE, SO THIS SHOULD BE EASY:

$$\Pi_T = \frac{T}{\rho D^2 V^2}$$

The only challenge might be selecting D^2 as the "length squared"

A good alternative formulation is:

$$\Pi_1 = \frac{T}{\rho N^2 D^4}$$

b) TORQUE is force times a lever arm, so for this one we need an EXTRA "L"

$$\Pi_Q = \frac{Q}{\rho D^3 V^2} \quad \text{OR} \quad \frac{Q}{\rho N^2 D^5}$$

c) To find a required speed we need to fill out the other Π-groups. The variables are: ρ, μ, D, V, N

we have used most of these in part a) & b) but we need take care of μ & N. The resulting Π-groups are:

$$\text{Reynold's Number} = \frac{D V \rho}{\mu}$$

$$\text{Specific speed} = \frac{V}{N D}$$

(⇐ this is called "J" in naval architecture)

Reynolds number gives us the water speed V:

$$V_m = \lambda \frac{\mu_m}{\mu_p} \frac{\rho_p}{\rho_m} V_p$$

d) Now that move have V_m we can use similitude of the advance coefficient "J" to solve for N_m.

$$\cancel{V_m D_m} \quad \frac{V_m}{N_m D_m} = \frac{V_p}{N_p D_p}$$

$$\cancel{V_m = N} \quad N_m = \frac{V_m}{V_p} \frac{D_p}{D_m} N_p$$

$$N_m = \lambda \frac{\mu_m}{\mu_p} \frac{\rho_p}{\rho_m} \lambda N_p = \lambda^2 N_p \frac{\mu_m}{\mu_p} \frac{\rho_p}{\rho_m}$$

from part (c)

e) $T = \Pi_T \rho D^2 V^2$

$$T_m = \frac{T_p}{\rho_p D_p^2 V_p^2} \rho_m D_m^2 V_m^2$$

given $D_p = \lambda D_m$

$D_p^2 = \lambda^2 D_m^2$

$$\frac{D_m^2}{D_p^2} = \frac{1}{\lambda^2}$$

$$T_m = \frac{T_p \rho_m V_m^2}{\rho_p \lambda^2 V_p^2}$$

from (c) $\frac{V_m}{V_p} = \lambda \frac{\mu_m}{\mu_p} \frac{\rho_p}{\rho_m}$

$$\frac{V_m^2}{V_p^2} = \lambda^2 \frac{\mu_m^2 \rho_p^2}{\mu_p^2 \rho_m^2}$$

$$T_m = T_p \frac{\rho_m}{\rho_p} \frac{\lambda^2}{\lambda^2} \frac{\mu_m^2}{\mu_p^2} \frac{\rho_p^2}{\rho_m^2}$$

$$= T_p \frac{\rho_p}{\rho_m} \frac{\mu_m^2}{\mu_p^2}$$

f) $Q = \Pi_Q \rho D^3 V^2$

$$Q_m = \frac{Q_p}{\rho_p D_p^3 V_p^2} \rho_m D_m^3 V_m^2$$

$$\frac{D_m^3}{D_p^3} = \frac{1}{\lambda^3}$$

$$Q_m = \frac{Q_p \rho_m V_m^2}{\rho_p \lambda^3 V_p^2}$$

$$Q_m = Q_p \frac{\rho_m}{\rho_p} \frac{\lambda^2}{\lambda^3} \frac{\mu_m^2}{\mu_p^2} \frac{\rho_p^2}{\rho_m^2}$$

$$= Q_p \frac{\rho_p}{\rho_m} \frac{\mu_m^2}{\mu_p^2} \frac{1}{\lambda}$$

g) No, this is not practical. The thrust of the model propeller is the same magnitude as the full-size ship. This can be 10- to 20,000 horsepower on move.

Full similitude is impractical and in practice we don't try for the Reynold's similarity.

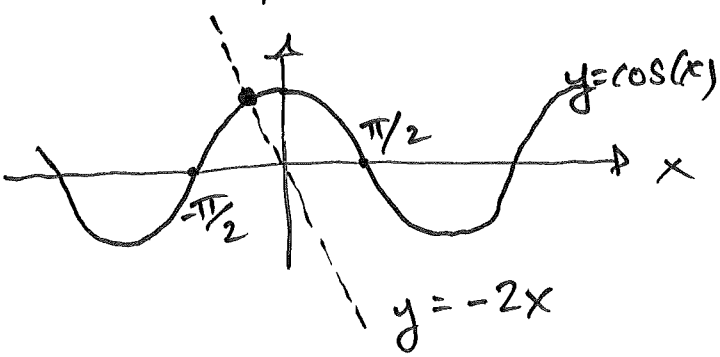
Problem 3 – 5 marks

Consider the function

$$f(x, y) = x^2 + y^2 + \sin(x) + \sin(y)$$

How many critical points does the function have and what is their classification? (Note: The question is not asking to find the exact positions of the critical points but rather to determine how many critical points there are and what are they.)

$f_x = 2x + \cos(x)$ $\qquad$ $f_y = 2y + \cos(y)$



$\Rightarrow 2x + \cos(x) = 0$

$\cos(x) = -2x$

one point x in $[-\frac{\pi}{2}, 0]$

$\Rightarrow 2y + \cos(y) = 0$

one point y in $[-\frac{\pi}{2}, 0]$.

$\Rightarrow$ There is only one critical point

$f_{xx} = 2 - \sin(x)$ $\quad$ $f_{yy} = 2 - \sin(y)$ $\quad$ $f_{xy} = 0$

$D = (f_{xx})(f_{yy}) - (f_{xy})^2 = (2 - \sin(x))(2 - \sin(y))$

$D > 0$ because $2 - \sin(x) > 0$ for all x and $2 - \sin(y) > 0$ for all y

$f_{xx} > 0$

$\Rightarrow$ The one critical point is a local minimum

Problem 4 – 8 marks

Find and classify the critical points of the function

$$f(x,y) = 2x^3 - 3x^2y - 12x^2 - 3y^2$$

$f_x = 6x^2 - 6xy - 24x = 6x(x - y - 4)$

$f_y = -3x^2 - 6y = -3(x^2 + 2y)$

$f_x = 0 \Rightarrow x = 0$ or $x = y + 4$

$f_y = 0 \Rightarrow x^2 = -2y$

$\Rightarrow \underline{x = 0,\ y = 0}$ or $(y+4)^2 = -2y$ $\quad \underline{y = -2,\ x = 2}$

$y^2 + 8y + 16 = -2y$

$y^2 + 10y + 16 = 0$ $\quad \underline{y = -8,\ x = -4}$

$(y+2)(y+8) = 0$

$\boxed{\Rightarrow \text{Critical points are } (0,0),\ (2,-2),\ (-4,-8)}$

$f_{xx} = 12x - 6y - 24 \quad f_{yy} = -6 \quad f_{xy} = -6x$

$(0,0)$ $\quad D = (-24)(-6) - 0^2 > 0$ $\quad$ $(0,0)$ is a

$f_{xx}(0,0) = -24$ $\quad$ <u>local maximum</u>

$(2,-2)$ $\quad D = (12)(-6) - (-12)^2 < 0$ $\quad$ $(2,-2)$ is a

<u>saddlepoint</u>

$(-4,-8)$ $\quad D = (-24)(-6) - (24)^2$ $\quad$ $(-4,-8)$ is a

<u>saddlepoint</u>

Problem 5 – 8 marks

Use the method of Lagrange multipliers to find the maximum and minimum values of the function

$$f(x,y) = e^{xy}$$

subject to the constraint $x^3 + y^3 = 16$.

$g(x,y) = x^3 + y^3 \qquad g_x = 3x^2 \quad g_y = 3y^2$

$f(x,y) = e^{xy} \qquad f_x = ye^{xy} \quad f_y = xe^{xy}$

$\nabla f = \lambda \nabla g \Rightarrow ye^{xy} = 3\lambda x^2 \; (1) \quad xe^{xy} = 3\lambda y^2 \; (2)$

$x \neq 0 \quad y \neq 0 \qquad \dfrac{ye^{xy}}{x^2} = \dfrac{xe^{yx}}{y^2} \qquad y^3 = x^3 \qquad \underline{x = y}$

$\Rightarrow x^3 + y^3 = 16 \qquad 2x^3 = 16 \qquad x = y = 2.$

If $x = 0$, then (1) says $y = 0$ but $0^3 + 0^3 \neq 16$

If $y = 0$, then (2) says $x = 0$ but $0^3 + 0^3 \neq 16$.

At $(2,2)$, $f(2,2) = e^4$.

Notice that as $x \to \infty$ then $y \to -\infty$ on $x^3 + y^3 = 16$

therefore $e^{xy} \to 0$ as $x \to \infty$. $(y \to -\infty)$

Also as $x \to -\infty$ then $y \to \infty$ on $x^3 + y^3 = 16$

therefore $e^{xy} \to 0$ as $x \to -\infty$ $(y \to \infty)$

$\Rightarrow e^4$ is the maximum value at $(2,2)$

There is no minimum value.

Problem 6 – 9 marks

Use the method of Lagrange multipliers to find the maximum and minimum values of the function

$$f(x, y, z) = x + 2y + 3z$$

subject to the constraints $x - y + z = 1$ and $x^2 + y^2 = 1$.

$f_x = 1 \quad f_y = 2 \quad f_z = 3$

$g(x,y,z) = x - y + z \quad g_x = 1 \quad g_y = -1 \quad g_z = 1$

$h(x,y,z) = x^2 + y^2 \quad h_x = 2x \quad h_y = 2y \quad h_z = 0$

$\nabla f = \lambda \nabla g + \mu \nabla h$

$$\left.\begin{aligned} 1 &= \lambda + 2x\mu \\ 2 &= -\lambda + 2y\mu \\ 3 &= \lambda \end{aligned}\right\} \begin{aligned} -2 &= 2x\mu \\ 5 &= 2y\mu \end{aligned}$$

$\Rightarrow \frac{-1}{x} = \frac{5}{2y} \Rightarrow x = \frac{-2}{5}y$

For $x^2 + y^2 = 1$, $\left(\frac{-2}{5}y\right)^2 + y^2 = 1 \quad \frac{4}{25}y^2 + y^2 = 1$

$\Rightarrow y = \pm \frac{5}{\sqrt{29}} \quad x = \mp \frac{2}{\sqrt{29}}$

$\Rightarrow \left(\frac{2}{\sqrt{29}}, \frac{-5}{\sqrt{29}}, 1 - \frac{2}{\sqrt{29}} - \frac{5}{\sqrt{29}}\right), \left(\frac{-2}{\sqrt{29}}, \frac{5}{\sqrt{29}}, 1 + \frac{2}{\sqrt{29}} + \frac{5}{\sqrt{29}}\right)$

$\Rightarrow \left(\frac{2}{\sqrt{29}}, \frac{-5}{\sqrt{29}}, 1 - \frac{7}{\sqrt{29}}\right), \left(\frac{-2}{\sqrt{29}}, \frac{5}{\sqrt{29}}, 1 + \frac{7}{\sqrt{29}}\right)$

$f\left(\frac{2}{\sqrt{29}}, \frac{-5}{\sqrt{29}}, 1 - \frac{7}{\sqrt{29}}\right) = \frac{2}{\sqrt{29}} + 2\left(\frac{-5}{\sqrt{29}}\right) + 3\left(1 - \frac{7}{\sqrt{29}}\right) \boxed{= \frac{-29}{\sqrt{29}} + 3 \text{ min.}}$

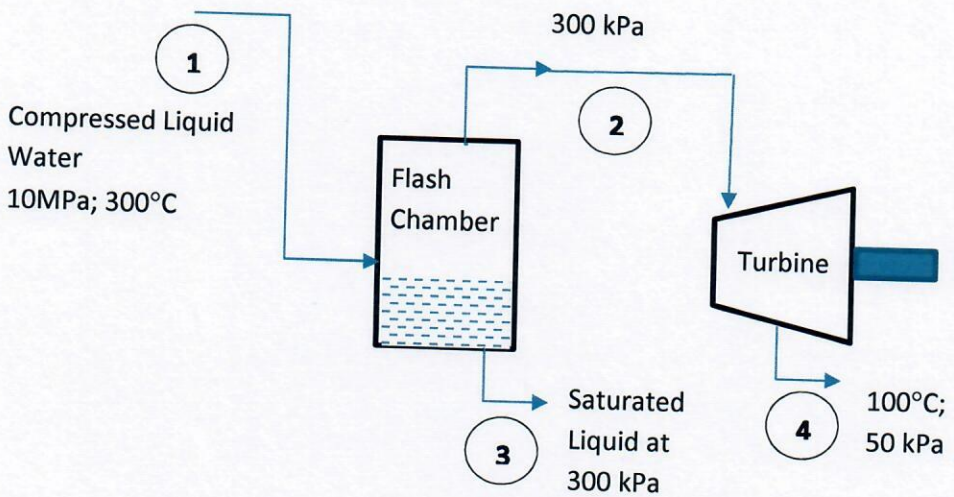
$f\left(\frac{-2}{\sqrt{29}}, \frac{5}{\sqrt{29}}, 1 + \frac{7}{\sqrt{29}}\right) = \frac{-2}{\sqrt{29}} + 2\left(\frac{5}{\sqrt{29}}\right) + 3\left(1 + \frac{7}{\sqrt{29}}\right) \boxed{= \frac{29}{\sqrt{29}} + 3 \text{ max.}}$

March 09, 2017 Test 4 MECH 222

Solutions

(10 marks) In an industrial process, compressed liquid water at 10 MPa and 300°C enters an insulated flash chamber. The flash chamber pressure is adjusted to 300 kPa. Saturated vapor leaving the flash chamber expands in a turbine and exits at 50 kPa and 100°C. If $\dot{m}_1 = 50\frac{kg}{s}$, determine:

a. (5 marks) The mass flowrate at point 2, in kg/s
b. (5 marks) The rate of work generated through the turbine, in W

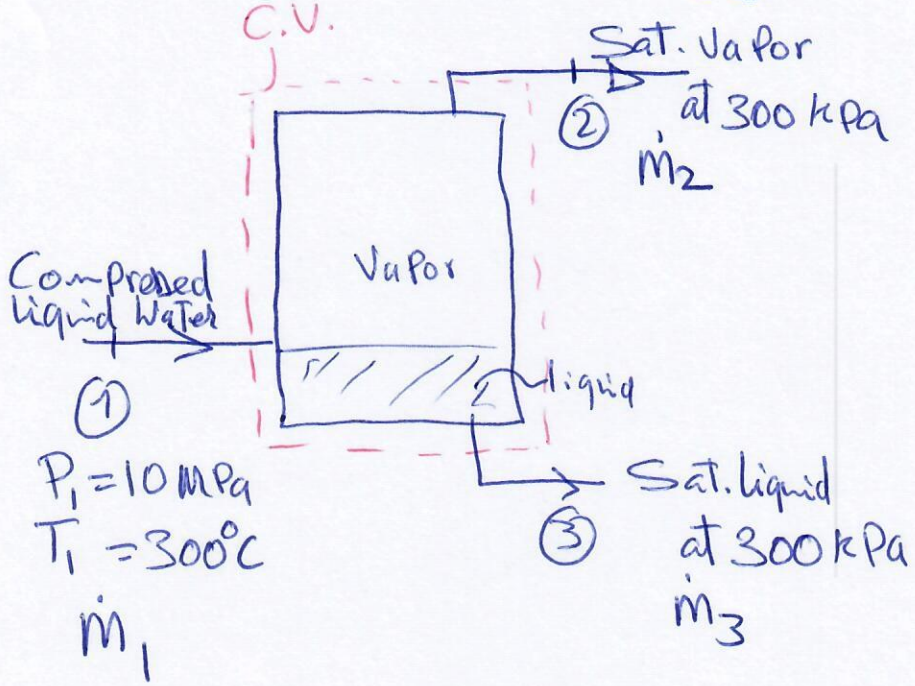


Please write your final answer in the Table below:

$\dot{m}_2 =$	Kg/s
$\dot{W} =$	W

Assumptions

* Steady state processes
* adiabatic processes
* ΔPE and ΔKE negligible



Flash chamber

Continuity Equation

$$\dot{m}_1 = \dot{m}_2 + \dot{m}_3 \longrightarrow \boxed{\dot{m}_3 = \dot{m}_1 - \dot{m}_2} \quad \text{I}$$

Energy Equation.

$$\dot{m}_1 h_1 = \dot{m}_2 h_2 + \dot{m}_3 h_3 \quad \text{II}$$

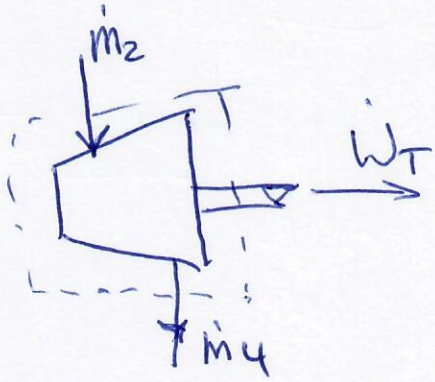
I & II $\quad \dot{m}_1 h_1 = \dot{m}_2 h_2 + \dot{m}_1 h_3 - \dot{m}_2 h_3 \longrightarrow \dot{m}_2 = \dfrac{h_1 - h_3}{h_2 - h_3}\dot{m}_1$

(1) $P_1 = 10\ MPa$, $T_1 = 300°C$ $\xrightarrow[\text{Table}]{\text{Comp. liq.}}$ $h_1 = 1342.31\ kJ/kg$

$P_2 = P_3 = 300\ kPa$ $\xrightarrow[\text{Table}]{\text{Sat.}}$ $\begin{cases} h_2 = h_g\big|_{300kPa} = 2725.30\ kJ/kg \\ h_3 = h_f\big|_{300kPa} = 561.45\ kJ/kg \end{cases}$

$$\dot{m}_2 = \frac{h_1 - h_3}{h_2 - h_3}\dot{m}_1 = \frac{1342.31 - 561.45}{2725.3 - 561.45}\,50 = 0.36 \times 50 = 18\ kg/s$$

b) $\dot{W}_T = ?$



<u>Continuity</u>

$\dot{m}_2 = \dot{m}_4 = 18\ kg/s$

<u>Energy balance</u>

$$\dot{m}_2 h_2 = \dot{W}_T + \dot{m}_4 h_4$$

$P_4 = 50\ kPa$, $T_4 = 100°C$ $\xrightarrow[\text{Table}]{\text{Superheated}}$ $h_4 = 2682.52\ kJ/kg$

$$18 \times 2725.30 = \dot{W}_T + 18 \times 2682.52$$

$$\dot{W}_T = 770.04\ kW \text{ or } 770{,}040\ W$$

TABLE B.1.4

Compressed Liquid Water

Temp. (°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)
	500 kPa (151.86 °C)				2000 kPa (212.42 °C)			
Sat.	0.001093	639.66	640.21	1.8606	0.001177	906.42	908.77	2.4473
0.01	0.000999	0.01	0.51	0.0000	0.000999	0.03	2.03	0.0001
20	0.001002	83.91	84.41	0.2965	0.001001	83.82	85.82	.2962
40	0.001008	167.47	167.98	0.5722	0.001007	167.29	169.30	.5716
60	0.001017	251.00	251.51	0.8308	0.001016	250.73	252.77	.8300
80	0.001029	334.73	335.24	1.0749	0.001028	334.38	336.44	1.0739
100	0.001043	418.80	419.32	1.3065	0.001043	418.36	420.45	1.3053
120	0.001060	503.37	503.90	1.5273	0.001059	502.84	504.96	1.5259
140	0.001080	588.66	589.20	1.7389	0.001079	588.02	590.18	1.7373
160	—	—	—	—	0.001101	674.14	676.34	1.9410
180	—	—	—	—	0.001127	761.46	763.71	2.1382
200	—	—	—	—	0.001156	850.30	852.61	2.3301
	5000 kPa (263.99 °C)				10000 kPa (311.06 °C)			
Sat	0.001286	1147.78	1154.21	2.9201	0.001452	1393.00	1407.53	3.3595
0	0.000998	0.03	5.02	0.0001	0.000995	0.10	10.05	0.0003
20	0.001000	83.64	88.64	0.2955	0.000997	83.35	93.32	0.2945
40	0.001006	166.93	171.95	0.5705	0.001003	166.33	176.36	0.5685
60	0.001015	250.21	255.28	0.8284	0.001013	249.34	259.47	0.8258
80	0.001027	333.69	338.83	1.0719	0.001025	332.56	342.81	1.0687
100	0.001041	417.50	422.71	1.3030	0.001039	416.09	426.48	1.2992
120	0.001058	501.79	507.07	1.5232	0.001055	500.07	510.61	1.5188
140	0.001077	586.74	592.13	1.7342	0.001074	584.67	595.40	1.7291
160	0.001099	672.61	678.10	1.9374	0.001195	670.11	681.07	1.9316
180	0.001124	759.62	765.24	2.1341	0.001120	756.63	767.83	2.1274
200	0.001153	848.08	853.85	2.3254	0.001148	844.49	855.97	2.3178
220	0.001187	938.43	944.36	2.5128	0.001181	934.07	945.88	2.5038
240	0.001226	1031.34	1037.47	2.6978	0.001219	1025.94	1038.13	2.6872
260	0.001275	1127.92	1134.30	2.8829	0.001265	1121.03	1133.68	2.8698
280					0.001322	1220.90	1234.11	3.0547
300					0.001397	1328.34	1342.31	3.2468

TABLE B.1.2 (*continued*)
Saturated Water Pressure Entry

		Enthalpy, kJ/kg			Entropy, kJ/kg-K		
Press. (kPa)	**Temp. (°C)**	**Sat. Liquid h_f**	**Evap. h_{fg}**	**Sat. Vapor h_g**	**Sat. Liquid s_f**	**Evap. s_{fg}**	**Sat. Vapor s_g**
0.6113	0.01	0.00	2501.3	2501.3	0	9.1562	9.1562
1.0	6.98	29.29	2484.89	2514.18	0.1059	8.8697	8.9756
1.5	13.03	54.70	2470.59	2525.30	0.1956	8.6322	8.8278
2.0	17.50	73.47	2460.02	2533.49	0.2607	8.4629	8.7236
2.5	21.08	88.47	2451.56	2540.03	0.3120	8.3311	8.6431
3.0	24.08	101.03	2444.47	2545.50	0.3545	8.2231	8.5775
4.0	28.96	121.44	2432.93	2554.37	0.4226	8.0520	8.4746
5.0	32.88	137.79	2423.66	2561.45	0.4763	7.9187	8.3950
7.5	40.29	168.77	2406.02	2574.79	0.5763	7.6751	8.2514
10	45.81	191.81	2392.82	2584.63	0.6492	7.5010	8.1501
15	53.97	225.91	2373.14	2599.06	0.7548	7.2536	8.0084
20	60.06	251.38	2358.33	2609.70	0.8319	7.0766	7.9085
25	64.97	271.90	2346.29	2618.19	0.8930	6.9383	7.8313
30	69.10	289.21	2336.07	2625.28	0.9439	6.8247	7.7686
40	75.87	317.55	2319.19	2636.74	1.0258	6.6441	7.6700
50	81.33	340.47	2305.40	2645.87	1.0910	6.5029	7.5939
75	91.77	384.36	2278.59	2662.96	1.2129	6.2434	7.4563
100	99.62	417.44	2258.02	2675.46	1.3025	6.0568	7.3593
125	105.99	444.30	2241.05	2685.35	1.3739	5.9104	7.2843
150	111.37	467.08	2226.46	2693.54	1.4335	5.7897	7.2232
175	116.06	486.97	2213.57	2700.53	1.4848	5.6868	7.1717
200	120.23	504.68	2201.96	2706.63	1.5300	5.5970	7.1271
225	124.00	520.69	2191.35	2712.04	1.5705	5.5173	7.0878
250	127.43	535.34	2181.55	2716.89	1.6072	5.4455	7.0526
275	130.60	548.87	2172.42	2721.29	1.6407	5.3801	7.0208
300	133.55	561.45	2163.85	2725.30	1.6717	5.3201	6.9918
325	136.30	573.23	2155.76	2728.99	1.7005	5.2646	6.9651
350	138.88	584.31	2148.10	2732.40	1.7274	5.2130	6.9404
375	141.32	594.79	2140.79	2735.58	1.7527	5.1647	6.9174
400	143.63	604.73	2133.81	2738.53	1.7766	5.1193	6.8958
450	147.93	623.24	2120.67	2743.91	1.8206	5.0359	6.8565
500	151.86	640.21	2108.47	2748.67	1.8606	4.9606	6.8212
550	155.48	655.91	2097.04	2752.94	1.8972	4.8920	6.7892
600	158.85	670.54	2086.26	2756.80	1.9311	4.8289	6.7600
650	162.01	684.26	2076.04	2760.30	1.9627	4.7704	6.7330
700	164.97	697.20	2066.30	2763.50	1.9922	4.7158	6.7080
750	167.77	709.45	2056.98	2766.43	2.0199	4.6647	6.6846
800	170.43	721.10	2048.04	2769.13	2.0461	4.6166	6.6627

TABLE B.1.3

Superheated Vapor Water

Temp. (°C)	v (m³/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg-K)	v (m³/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg-K)
	$P = 10$ kPa (45.81°C)				$P = 50$ kPa (81.33°C)			
Sat.	14.67355	2437.89	2584.63	8.1501	3.24034	2483.85	2645.87	7.5939
50	14.86920	2443.87	2592.56	8.1749	—	—	—	—
100	17.19561	2515.50	2687.46	8.4479	3.41833	2511.61	2682.52	7.6947
150	19.51251	2587.86	2782.99	8.6881	3.88937	2585.61	2780.08	7.9400
200	21.82507	2661.27	2879.52	8.9037	4.35595	2659.85	2877.64	8.1579
250	24.13559	2735.95	2977.31	9.1002	4.82045	2734.97	2975.99	8.3555
300	26.44508	2812.06	3076.51	9.2812	5.28391	2811.33	3075.52	8.5372
400	31.06252	2968.89	3279.51	9.6076	6.20929	2968.43	3278.89	8.8641
500	35.67896	3132.26	3489.05	9.8977	7.13364	3131.94	3488.62	9.1545
600	40.29488	3302.45	3705.40	10.1608	8.05748	3302.22	3705.10	9.4177
700	44.91052	3479.63	3928.73	10.4028	8.98104	3479.45	3928.51	9.6599
800	49.52599	3663.84	4159.10	10.6281	9.90444	3663.70	4158.92	9.8852
900	54.14137	3855.03	4396.44	10.8395	10.82773	3854.91	4396.30	10.0967
1000	58.75669	4053.01	4640.58	11.0392	11.75097	4052.91	4640.46	10.2964
1100	63.37198	4257.47	4891.19	11.2287	12.67418	4257.37	4891.08	10.4858
1200	67.98724	4467.91	5147.78	11.4090	13.59737	4467.82	5147.69	10.6662
1300	72.60250	4683.68	5409.70	14.5810	14.52054	4683.58	5409.61	10.8382
	100 kPa (99.62°C)				200 kPa (120.23°C)			
Sat.	1.69400	2506.06	2675.46	7.3593	0.88573	2529.49	2706.63	7.1271
150	1.93636	2582.75	2776.38	7.6133	0.95964	2576.87	2768.80	7.2795
200	2.17226	2658.05	2875.27	7.8342	1.08034	2654.39	2870.46	7.5066
250	2.40604	2733.73	2974.33	8.0332	1.19880	2731.22	2970.98	7.7085
300	2.63876	2810.41	3074.28	8.2157	1.31616	2808.55	3071.79	7.8926
400	3.10263	2967.85	3278.11	8.5434	1.54930	2966.69	3276.55	8.2217
500	3.56547	3131.54	3488.09	8.8341	1.78139	3130.75	3487.03	8.5132
600	4.02781	3301.94	3704.72	9.0975	2.01297	3301.36	3703.96	8.7769
700	4.48986	3479.24	3928.23	9.3398	2.24426	3478.81	3927.66	9.0194
800	4.95174	3663.53	4158.71	9.5652	2.47539	3663.19	4158.27	9.2450
900	5.41353	3854.77	4396.12	9.7767	2.70643	3854.49	4395.77	9.4565
1000	5.87526	4052.78	4640.31	9.9764	2.93740	4052.53	4640.01	9.6563
1100	6.33696	4257.25	4890.95	10.1658	3.16834	4257.01	4890.68	9.8458
1200	6.79863	4467.70	5147.56	10.3462	3.39927	4467.46	5147.32	10.0262
1300	7.26030	4683.47	5409.49	10.5182	3.63018	4683.23	5409.26	10.1982
	300 kPa (133.55°C)				400 kPa (143.63°C)			
Sat.	0.60582	2543.55	2725.30	6.9918	0.46246	2553.55	2738.53	6.8958
150	0.63388	2570.79	2760.95	7.0778	0.47084	2564.48	2752.82	6.9299
200	0.71629	2650.65	2865.54	7.3115	0.53422	2646.83	2860.51	7.1706

TABLE B.1.2

Saturated Water Pressure Entry

Press. (kPa)	Temp. (°C)	Specific Volume, m³/kg			Internal Energy, kJ/kg		
		Sat. Liquid v_f	Evap. v_{fg}	Sat. Vapor v_g	Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g
0.6113	0.01	0.001000	206.131	206.132	0	2375.3	2375.3
1	6.98	0.001000	129.20702	129.20802	29.29	2355.69	2384.98
1.5	13.03	0.001001	87.97913	87.98013	54.70	2338.63	2393.32
2	17.50	0.001001	67.00285	67.00385	73.47	2326.02	2399.48
2.5	21.08	0.001002	54.25285	54.25385	88.47	2315.93	2404.40
3	24.08	0.001003	45.66402	45.66502	101.03	2307.48	2408.51
4	28.96	0.001004	34.79915	34.80015	121.44	2293.73	2415.17
5	32.88	0.001005	28.19150	28.19251	137.79	2282.70	2420.49
7.5	40.29	0.001008	19.23674	19.23775	168.76	2261.74	2430.50
10	45.81	0.001010	14.67254	14.67355	191.79	2246.10	2437.89
15	53.97	0.001014	10.02117	10.02218	225.90	2222.83	2448.73
20	60.06	0.001017	7.64835	7.64937	251.35	2205.36	2456.71
25	64.97	0.001020	6.20322	6.20424	271.88	2191.21	2463.08
30	69.10	0.001022	5.22816	5.22918	289.18	2179.22	2468.40
40	75.87	0.001026	3.99243	3.99345	317.51	2159.49	2477.00
50	81.33	0.001030	3.23931	3.24034	340.42	2143.43	2483.85
75	91.77	0.001037	2.21607	2.21711	394.29	2112.39	2496.67
100	99.62	0.001043	1.69296	1.69400	417.33	2088.72	2506.06
125	105.99	0.001048	1.37385	1.37490	444.16	2069.32	2513.48
150	111.37	0.001053	1.15828	1.15933	466.92	2052.72	2519.64
175	116.06	0.001057	1.00257	1.00363	486.78	2038.12	2524.90
200	120.23	0.001061	0.88467	0.88573	504.47	2025.02	2529.49
225	124.00	0.001064	0.79219	0.79325	520.45	2013.10	2533.56
250	127.43	0.001067	0.71765	0.71871	535.08	2002.14	2537.21
275	130.60	0.001070	0.65624	0.65731	548.57	1991.95	2540.53
300	133.55	0.001073	0.60475	0.60582	561.13	1982.43	2543.55
325	136.30	0.001076	0.56093	0.56201	572.88	1973.46	2546.34
350	138.88	0.001079	0.52317	0.52425	583.93	1964.98	2548.92
375	141.32	0.001081	0.49029	0.49137	594.38	1956.93	2551.31
400	143.63	0.001084	0.46138	0.46246	604.29	1949.26	2553.55
450	147.93	0.001088	0.41289	0.41398	622.75	1934.87	2557.62
500	151.86	0.001093	0.37380	0.37489	639.66	1921.57	2561.23
550	155.48	0.001097	0.34159	0.34268	655.30	1909.17	2564.47
600	158.85	0.001101	0.31457	0.31567	669.88	1897.52	2567.40
650	162.01	0.001104	0.29158	0.29268	683.55	1886.51	2570.06
700	164.97	0.001108	0.27176	0.27286	696.43	1876.07	2572.49
750	167.77	0.001111	0.25449	0.25560	708.62	1866.11	2574.73
800	170.43	0.001115	0.23931	0.24043	720.20	1856.58	2576.79