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The following updates and corrections are pending for the second printing of this text:

Page/Location	Was	Change to
p. 9, Example 1.7, lines 9 and 10	600 Nm = 250 (Nm V^2) + 220.6 Nm V = 1.23 m/s	6000 Nm = 250V^2 + 220.6 Nm V = 4.81 m/s
p. 10, line 7	½ mV^2 = WΔxm	½ mV^2 = FΔx
p. 17	Example 1.15	Example 1.16
p. 19, Example 2.1, Solution—1st equation 2nd equation	$Q = w$ . . . . = 315 kJ/kg	$Q = m$ . . . . . . = 315 kJ
p. 27, Example 2.13, Solution, line 7 Line 8 Line 9 Line 12	$Q = \Delta u = wCv\Delta t$ $Pv = mRT$ w = . . . $\Delta s = mCv \ln (T_2/T_1)$	$q = \Delta u = mCv\Delta t$ $Pv = wRT$ m = . . . $\Delta s = wCv \ln (T_2/T_1)$
p. 29, Example 2.17, Solution—line 2	T_2 = (350 – 50) + 300 = 573°K	T_2 = (350 – 50) + 273 = 573°K
p. 33, Example 2.23, Solution, line 2 line 5 last line	. . . and ΔKE = ΔPE = 0 . . . = 2945.2 kJ/kg. . . . (2945.2 – 2423) = <u>2611 kJ</u>	. . . and ΔKE = ΔPE = 0, Q = 0 . . . = 2045.2 kJ/kg. . . . (2045.2 – 2423) = <u>1889 kJ</u>
p. 38, Solution	W_{H_2O} [4 instances] W_{BRINE} [2 instances]	$\dot{m}_{H_2O}$ $\dot{m}_{BRINE}$

p. 48, lines 6 and 7	Q = (0.85)(6.5) . . . $Q = 16.9\ m^3/s = 1016\ m^3/min$	Q = (0.85)(0.5) . . . $Q = 18.82\ m^3/s = 1129\ m^3/min$
p. 71, line 7 (Fourier number)	. . . + (sec)	. . . (sec) [delete plus sign]
p. 76, Example 5.2, Solution—line 5	T = 1424 Nm	$T = 1424 \times 10^3$ Nm
Line 6	$I_p = \frac{\pi d^4}{64}$	$I_p = \frac{\pi d^4}{32}$
Line 7	$I_p = \frac{\pi(0.4)^4}{64} = 0.001256\,m^4$	$I_p = \frac{\pi(0.4)^4}{32} = 0.002513\,m^4$
Line 8	TR/T_p	TR/I_p
Line 9	$S_s = \frac{(1424\ Nm)(0.20\ m)}{0.001256\ m^4}$	$S_s = \frac{(1424 \times 10^3\ Nm)(0.20\,m)}{0.002513\,m^4}$
Line 10	$S_s = 226{,}751\ N/m^2$	$S_s = 113{,}376 \times 10^3\ N/m^2$
p. 80, line 4	d = 0.0356 cm	d = 0.0356 m = 3.56 cm
p. 90, line 2	P_p = 117,810 N	P_p = 11,781 N
Line 5	. . . = (117,810 N)(7/35) = 23,562 N	. . . = (11,781 N)(7/35) = 2356.2 N
p. 101, Example 5.36 Solution, line 2	$\tau = 150 \times 10^6 = \frac{20\ kn}{\frac{\pi}{4} d^2}$	$\tau = 150 \times 10^6\ Pa = \frac{20\ kN}{\frac{\pi}{4} d^2}$
line 3	$d^2 \frac{4}{\pi}(150 \times 10^3) = 20$	$d^2 \frac{\pi}{4}(150 \times 10^3)\ Pa = 20\ N$
line 4	$d^2 = \frac{20\pi}{4}\left(\frac{1}{150 \times 10^3}\right)$ $d = 0.0102\ m, or\ 10.2\ mm$	$d^2 = \frac{20(4)}{\pi}\left(\frac{1}{150 \times 10^3}\right)$ $d = 0.013\,m,\ or\ 13\,mm$
p. 109, Example 6.2, line 8	104.3 meters	213.38 meters
p. 129, Example 7.10, Solution—Line 2	$... = P_1 V_1 \ln \frac{P_2}{P_1}$	$... = P_1 V_1 \ln \frac{P_1}{P_2}$
Line 4	-5545 [2 instances]	-554,517

Line 5	-5545 123.9 hp	-554,517 12,390 hp
p. 134, Example 7.13 Solution	work = . . . [7 instances]	$work_{in}$ = . . .
p. 140, line 17 line 23 2nd line from bottom page	*A/F* = ... 16.8 0.75 CH_4 . . . subscript C_2H_2	*A/F* = . . . = 16.8 [insert equals sign before 16.8] 0.75 CH_4 . . . = [insert equals sign at end of line] subscript C_2H_6
p. 141, line 2	Missing three minus signs	Insert minus signs between 2nd and 3rd terms in bracketed portions—three instances
p. 151, line 4 Line 5	 Equation 9.3 includes . . .	Label this equation **(9.4)** Equations 9.3 and 9.4 include . . .
p. 152, last line	m_1 = 110 kg/s	m_1 = 1110 kg/s
p. 153, lines 2 and 3 from bottom		This should be all one equation without a line break—the parenthetical terms in line 2 from the bottom should be moved up to the end of the preceding line
p. 174, Example 10.2, line 9	306^2	3.06^2
p. 179, line 18 line 24 (in denominator)	0.9 = . . . $(100 \times 10^3\ N/m^2)$	0.09 = . . . $(1.0 \times 10^3\ N/m^2)$
p. 193, Exhibit 7 Row 2, column 5 Row 2, column 6 Line 4 from bottom Line 3 from bottom Line 2 from bottom Last line	 1173 703 . . . (1.2 kJ/kg) . . . ΔT = 500 . . . + 500 T_3 = 1173 °K	 1270.6 761 . . . (1.004 kJ/Kg °K). . . ΔT = 597.6 . . . + 597.6 T_3 = 1270.6 °K

p. 194, line 3		
p. 209, Example 12.5 solution (a) table of values at states (c) COP equation (d) last equation	 79.48 79.48 79.48 41.3 tons	 71.33 71.33 71.33 43.6 tons
p. 217, line 7	*Q* = 662,620 Btu/lb	*Q* = 662,620 Btu/hr
p. 225, Example 13.13, line 3	. . . dew point of 59°F.	. . . dew point of saturated air at 59°F.
p. 239, Solution, line 2	Refer to Exhibit 4;	Refer to Exhibit 9;

Example 5.17

Neglecting spoke effect, calculate the energy stored in the rim of a flywheel made of cast iron 60 cm in diameter with a rim 10 cm wide by 8 cm deep running at 1000 rpm.

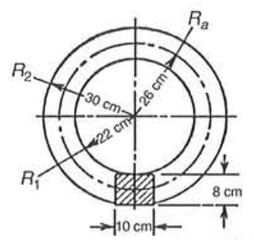

Exhibit 4

Solution

Let W be the weight of flywheel in newtons, ρ the radius of gyration in meters, R_1 the internal radius of the rim in meters, R_2 the external radius of the rim in meters, ω the angular velocity in radians per second, and the density of cast iron 7887 kg/m^3.

Weight of flywheel

$$W = (0.10)\text{m}(0.08)\text{m}(2\pi 0.26)\text{m}(7887)\text{kg/m}^3$$

$$W = 103 \text{ kg}$$

$$\rho = \frac{1}{2}\sqrt{R_1^{\,2} + R_2^{\,2}} = \frac{1}{2}\sqrt{(0.22)^2 + (0.30)^2} = 0.186 \text{ m}$$

$$\text{Angular velocity } \omega = \frac{\text{rpm} \times 2\pi}{60} = \frac{(1000)(2\pi)}{60} = 104.7 \text{ rad/s}$$

Energy stored in rim

$$E = \frac{W\rho^2\omega^2}{2} = \frac{(103 \text{ kg})(0.186 \text{ m})^2[(104.7)\text{rad/s}]^2}{2}$$

$$E = 19{,}531 \text{ Nm}$$

Example 5.18

A 50 kg wheel 40 cm in diameter turning at 150 rpm in stationary bearings is brought to rest by pressing a brake shoe radially against a rim with a force of 88 N. The radius of gyration of the wheel is 15 cm, and the coefficient of the friction of the brake is 0.25. How many revolutions will the wheel make in coming to rest?

Solution

$$\omega = \frac{150 \text{ rpm}}{60} \times 2\pi = 15.7 \text{ rad/sec}$$

$$E = \frac{W\rho^2\omega^2}{2g} = \frac{(50 \text{ kg})(0.15 \text{ m})^2(15.7 \text{ rad/s})^2}{2}$$

$$E = 138.6 \text{ Nm}$$

Frictional force to stop the car wheel is (88 N)(μ) = (88 N)(0.25) = 22 N on perimeter.

Wheel perimeter is $\pi D = \pi(0.4) = 1.26$ m.

Distance force must travel is

$$\frac{138.6 \text{ Nm}}{22 \text{ N}} = 6.3 \text{ m.}$$

$$\text{Number of revolutions} = \frac{6.3 \text{ m}}{1.26 \text{ m/rev}} = 5 \text{ rev}$$

The theoretical steam rate is $\frac{2545 \text{ Btu/hp-hr}}{386 \text{ Btu/lb}} = 6.6$ lb/hp-hr. Thus, the *Rankine efficiency* of the turbine is 6.6/10.5, or 63%.

The *theoretical thermal efficiency* of the cycle is the ratio between the available (1322–936 = 386 Btu per lb) and the energy supplied to the condensate above 32°F, which is

(Enthalpy at inlet) – Condensate enthalpy = Energy supplied

1322 Btu/lb – 69 Btu/lb = 1253 Btu/lb.

Then the *ideal Rankine cycle* is determined as 386/1253, or 30.8%.

The Rankine cycle may be improved by increasing the initial pressure and temperature. Then, in order to avoid excessive condensation in the lower pressure stages, this pressure increase must go hand-in-hand with an increase in temperature.

Example 9.13

In an ideal power plant, the steam is supplied at 140 bars and 520°C to an isentropic turbine. The steam is exhausted at 10 bars, reheated to 520°C, and supplied to the low pressure turbine. Steam exhausts at 0.08 bar.

Determine:

(a) Cycle efficiency

(b) If there were no reheat and the exhaust was still at 0.08 bar, what would be the cycle efficiency?

(c) What is the chief advantage of a reheat?

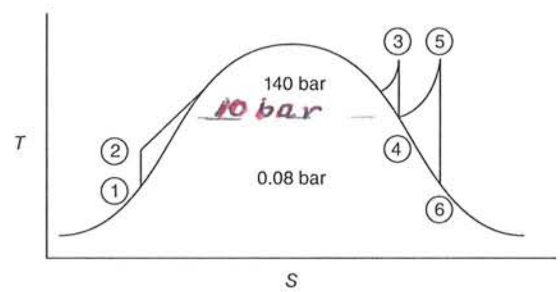

Exhibit 5

Solution

Construct a table of values:

	1	2	3	4	5	6
P	0.08	140	140	10	0	0.08
T			520		520	
H	173.88	187.99	3377.8	2717.6	3522.05	2447.7
S			←	6.4610	7.8171	→
x				0.97		0.946

The process from 3 to 4 is isentropic.

$$T_4 = T_3\left(\frac{P_4}{P_3}\right)^{(k-1)/k}$$

$$T_4 = 1173\left(\frac{1}{6}\right)^{(1.4-1)/1.4} = 703°\text{K}$$

(a) Regenerator effectiveness:

$$E_R = \frac{h_x - h_2}{h_4 - h_2} = \frac{T_x - T_2}{T_4 - T_2} = \frac{673 - 497}{703 - 497} = 85\%$$

(b) Mass flow rate of air:

$$\text{Pow} = \dot{m}(\text{Work net})$$

$$\dot{m} = \frac{\text{Power}}{\text{Work net}}$$

$$\dot{m} = \frac{(6000 \text{ hp})(0.7457 \text{ kJ/hp-s})}{[(h_3 - h_4) - (h_2 - h_1)] \text{ kJ/kg}}$$

$$\dot{m} = \frac{(6000)(0.7457 \text{ kJ/hp-s})}{1.2[(1173 - 703) - (497 - 298)]\text{kJ/kg}} = 13.8\text{kg/s}$$

(c) Thermal efficiency:

$$\eta_t = \frac{\text{Energy wanted}}{\text{Energy that costs \$}} = \frac{w_T - w_c}{600 \text{ kJ/kg}}$$

$$\eta_t = \frac{271}{600} = 45\%$$

Often we want to change the velocity of flow of gases and vapors. The device most convenient to use for this is the nozzle. The nozzle may be designed to either increase or decrease the velocity. When high speed is required, as with military aircraft where conservation of momentum is used, the exit speed of the exhaust products needs to be very high.

Example 11.4

Air (constant specific heat) enters the isentropic diffuser of a turbojet engine at 1100 ft/sec, pressure of 6 psia and temperature of 400°R. The air decelerates to a low velocity as it enters an 80% efficient compressor with a pressure ratio of 12. Fuel is injected into the combustion chamber, producing heat at a rate of 800 Btu/lbm of air flowing through the turbine. The turbine is 85% efficient and is connected to an isentropic nozzle. Exhibit 8 shows the engine and its *TS* characteristics.

Determine (a) the velocity of the gas leaving the met and (b) thermal efficiency of the engine.