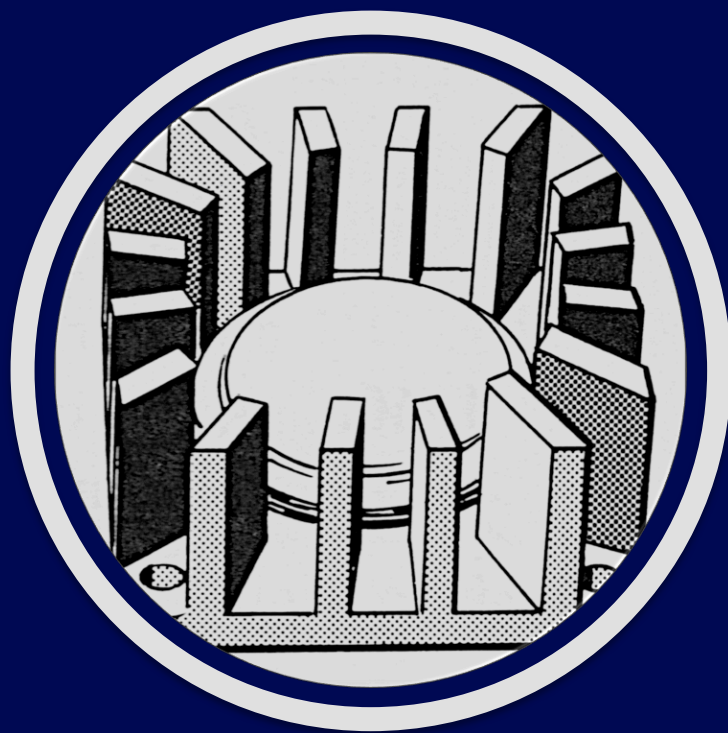


BASIC HEAT TRANSFER

Third Edition



A. F. MILLS
C. F. M. COIMBRA

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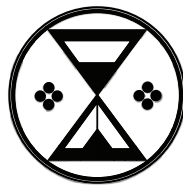
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Solutions Manual

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ANSWERS TO SELECTED EXERCISES

(A) ODD-NUMBERED EXERCISES

Chapter 1

- 1-3 (i) 83.8 MW, (ii) 33.9 kg/s
1-5 (i) 14.9, (ii) 13.6 cm, (iii) 1.14
1-7 10.1 W/m^2 ; 18.0°C and 2.0°C
1-9 1.22 cm
1-11 39.6 W (34.0 kcal/h)
1-15 (i) $8430 \text{ W/m}^2 \text{ K}$, (ii) $42.1 \text{ W/m}^2 \text{ K}$, (iii) $97.5 \text{ W/m}^2 \text{ K}$
1-17 66.8 W
1-19 43.3°C
1-21 (i) 207 W, (ii) \$12.1
1-23 5020 W
1-25 66°C
1-27 12.5 K/W , $4.995 \times 10^{-2} \text{ K/W}$
1-29 $1.33 \times 10^5 \text{ s}$
1-33 -29.7°C , 32.9°C
1-35 20°C
1-37 $3.31 \text{ W/m}^2 \text{ K}$
1-39 (iii) 3640 W
1-41 (i) 270 K, (ii) 274 K, (iii) 276 K, 277 K
1-43 630 s
1-45 48 h
1-47 (i) $9170 \text{ W/m}^2 \text{ K}$, (ii) 0.068
1-49 17.2 min
1-51 (i) 0.51°C , (ii) 30°C
1-53 (iii) 0.614 K, -1.509 rd; 2.0 K, -1.37 rd
1-55 316 K
1-57 50.1°C , 2.66 h
1-59 43.3 s
1-61 19.9 s, 5.5 K/s
1-63 (i) 6.04 W, (ii) 37 min
1-75 (i) $0.155 [\text{W/m}^2 \text{ K}]^{-1}$, (ii) 0.258 clo, (iii) $6 \text{ W/m}^2 \text{ K}$

Chapter 2

- 2-1 $T = -(1/a - T_0) \pm [(1/a - T_0)^2 - T_1^2 + (2/a - 2/T_0)T_1 - 2qx/k_0a]^{1/2}$
2-3 (i) $2k_A k_B / (k_A + k_B)$; (ii) $(k_A + k_B)/2$
2-9 19.2°C
2-11 $246 \text{ W/m}^2 \text{ K}$
2-13 (i) 32.9 W/m, (ii) 31.9 W/m
2-15 3.80 W/m

2-17	0.12 W/m K
2-19	0.134 W/m K
2-21	(iii) 870,000 \$/yr
2-23	765 W/m
2-25	(i) 646 W/m, (ii) 630 W/m, (iii) 662 W/m
2-27	No
2-31	19 mm
2-37	(i) $2k/h_o$, (ii) $(3k/2\alpha)^2$
2-41	2.29 cm
2-43	(i) 4.70 W, (ii) 5.75 MW/m ³ , (iii) 1.47 kW/m ²
2-45	84.1 A
2-47	(i) 165 MW/m ³ , (ii) 93.3 W
2-53	2.42 m
2-55	705°C
2-57	185°C
2-61	14.3 kW
2-67	49.4 W/m ² K
2-69	Yes
2-71	(i) 1.83 cm, (ii) 3.42 cm
2-77	(i) 58.7 W/m K, (ii) ± 0.5 K
2-81	219 W
2-83	959 W/m ² K
2-87	28 cm
2-89	5.7 K
2-93	2.11 W
2-95	221°C
2-97	(ii) 7%
2-99	25.6 A
2-101	53.5 W
2-103	323.1 K; 516.2 W/m ²
2-107	(i) 4.68 W, (ii) 5.66 W (Item 8); 5.85 W (Item 9); 5.86 W (Item 10)
2-109	0.10 (10% of bare tube value)
2-111	0.360
2-115	440%
2-117	(i) 1918 W
2-119	0.132 (13% of bare tube value)

Chapter 3

3-5	2030 K/m
3-7	359.8 K
3-9	(ii) 365 K
3-11	(ii) 390.8 K
3-17	$T_{\max} - T_{\text{sat}} = 0.366q_s a/k$
3-19	(i) 9.34 W/m, (ii) 9.26 W/m
3-21	489 K

3-25	$1.03 \times 10^{-2} \text{ K/m}$
3-27	(i) 178 W/m, (ii) 176 W/m
3-29	42.0 W
3-31	(i) 76.1 W/m, (ii) 138.4 W/m
3-35	502 W/m^2
3-39	849.6 W/m^2
3-43	29.4°C; 189 degrees
3-45	12.6 W/m K
3-49	(i) 96.9°C, (ii) 91.6°C, (iii) 70.5°C, (iv) 63.2°C
3-51	$406 \text{ W/m}^2 \text{ K}$
3-53	1430 s
3-55	(i) 38.1 s, (ii) 118 s, (iii) 148 s, (iv) 94 s
3-57	2.2 s
3-59	142 s
3-61	238 s, 3021 s
3-65	2840 s
3-67	281 K
3-69	4.44 h; 59%
3-71	(i) 244°C, (ii) 145°C, (iii) 147°C
3-73	2100 s
3-75	4200 s
3-77	(i) 86.6°C, (ii) 100°C
3-83	6.580
3-85	$8.4 \times 10^{-8} \text{ m}^2/\text{s}$
3-127	54.1°C

Chapter 4

4-1	365.6 K
4-9	85 W/m
4-11	$13,920 \text{ W/m}^2 \text{ K}$; $3.98 \times 10^3 \text{ Pa/m}$
4-13	$18,020 \text{ W/m}^2 \text{ K}$; $3.92 \times 10^4 \text{ Pa/m}$
4-15	$28.1 \text{ W/m}^2 \text{ K}$; 5.09 Pa/m
4-17	(i) 12.06; 61,200 $\text{W/m}^2 \text{ K}$, (ii) 14.07; 71,350 $\text{W/m}^2 \text{ K}$
4-19	318.1 K
4-23	$920 \text{ W/m}^2 \text{ K}$; 13.85 kPa
4-25	$222.5 \text{ W/m}^2 \text{ K}$; 372.3 K; 6.62 kPa
4-31	635, 631, 291 $\text{W/m}^2 \text{ K}$
4-39	0.294 N/m; -951 W/m
4-41	3370 W
4-43	312 K
4-49	11.7 cm/s
4-51	328.5 K; 353.8 K
4-53	(i) 0.615 N, (ii) 1.48, (iii) 1070 kW
4-55	19.5 cents/m day
4-57	0.58 W

4-59	47.2°C
4-63	138 W/m
4-65	530.8 K
4-67	3.47 m/s, $T_s(0.1 \text{ m}) = 322.3 \text{ K}$
4-69	26,000 K
4-71	549 s; 9.16 kg
4-73	Air: (i) 0.091 m/s, (ii) 100 K; Water: (i) $9.9 \times 10^{-4} \text{ m/s}$, (ii) 0.56 K
4-77	(i) 55.8 W; 24.6 W, (ii) 631 W; 212 W
4-79	1.20 W
4-81	4.09 W from each side
4-83	804 s, 8.78 kg
4-85	99.0 min
4-89	118 W
4-91	0.00525 m, 10.94 W/m
4-93	18.4 m
4-97	$\epsilon = 0.86$, $k = 0.881 \text{ W/m K}$
4-99	32 min
4-101	(i) 119 W/m^2 , (ii) 114 W/m^2 , (iii) 113 W/m^2
4-103	264 W/m
4-105	3.73 k; 5.63 W
4-107	42,900 W; 24,700 W
4-111	(i) 1.6 m/s, (iv) 7.9 m/s
4-113	$101 \text{ W/m}^2 \text{ K}$; 712 Pa
4-117	17; 36.7 Pa
4-119	2312 Pa/m ; $134 \text{ W/m}^2 \text{ K}$; 413 m^{-1} ; 41.3 m
4-125	863 K
4-127	(i) 154.6 W, (ii) 10.5 kW
4-129	88.2%
4-133	$6,860 \text{ Pa/m}$; $54,500 \text{ W/m}^2 \text{ K}$
4-135	3.57 mm; 15,590; 9.54×10^{-2} ; 359 N/m^2 ; 3.26×10^{-3} ; $3.01 \times 10^7 \text{ W/m}^2$

Chapter 5

5-1	(i) 1.27 W, (ii) 59.7 W, (iii) 34,700 W
5-3	(i) 4900 kW, (ii) 0.72
5-5	0.919, $520.3 \text{ W/m}^2 \text{ K}$, $506.8 \text{ W/m}^2 \text{ K}$
5-9	$T = T_s + (3/4)(\mu_b^2/k)[5 + 4(y/b) - (y/b)^4]$
5-11	$T = T_s - (\mu_b^2/k)[1 - (r/R)^4]$
5-15	-40.7 Pa/m
5-17	$7.314/(D/2)\text{Re}_D\text{Pr}$
5-25	56.0 W; 74.9 W
5-27	$1.73 \times 10^4 \text{ W/m}^2$; 21% increase
5-29	$C_{fx} = 0.654\text{Re}_x^{-1/2}$; $\text{Nu}_x = 0.350\text{Re}_x^{1/2}\text{Pr}^{1/3}$

Chapter 6

6-5	(i) 9 kW/m ² , (ii) 21 kW/m ² , (iii) 1.063 kW/m ² , (iv) 22.06 kW/m ²
6-7	0.0775; 0.155; 0.155, 0.0775
6-13	(i) 25.0 W, (ii) 85.1 W; -5.7 W
6-15	0.25, 0.0625, 0.0278
6-17	799 W, 1346 K, 1157 K
6-19	(i) 62%, (ii) 32%
6-21	1059 K; error reduced from 186 K to 109 K
6-23	Zero
6-25	609.5 K
6-29	(i) 1473 W, (ii) 432 W
6-31	2.62 m
6-33	264 kW/m ²
6-35	14.2 MW
6-37	(i) 214.3 kW/m ² , (ii) 210.8 kW/m ²
6-39	(i) 4.33x10 ⁵ , (ii) 4.312x10 ⁵ , (iii) 4.308x10 ⁵ , (iv) 4.308x10 ⁵ W/m
6-43	4.62 W; 28.79 W; 7.99 W
6-47	70.9 kW/m
6-49	(i) 66.89 W/m, (ii) 66.86 W/m
6-51	1.18 W
6-53	441 kW/m
6-59	(i) 760.2 K, (ii) 582.9 K, (iii) 27.6 W, (iv) 100 W
6-61	17.3 kW
6-63	4.23 W
6-65	0.74; 269 K (Brunt correlation)
6-67	202.9 W/m ²
6-69	370.5 K; 349.2 K
6-71	0.9385
6-73	37 W/m ²
6-75	1.248 W/m ²
6-77	Yes; maybe
6-79	247.6 K
6-83	363 K, 369 K
6-85	321.0 K, 45.7%
6-87	Yes
6-89	$H/(R^2+H^2/4)^{1/2}$
6-91	(i) 0.405 W/m, (ii) 0.398 W/m, (iii) 0.398 W/m
6-93	(i) 163 W, (ii) 260 W
6-95	(i) 256 W/m, (ii) 273 W/m
6-99	(i) 0.071, (ii) 0.24
6-103	737.5 kW
6-105	(i) 809 W/m ² , (iii) 0.13
6-107	1.6°C
6-109	0.027
6-111	0.44

- 6-113 205.5K
 6-115 (i) 0, (ii) 0, (iii) 0.873
 6-117 (i) 0.748, (ii) 120°C
 6-121 0.190, 0.370, 0.544
 6-123 1952 kW/m
 6-125 110.2 kW/m
 6-127 $\dot{Q}_{\text{rad}}/L = 17.2 \text{ kW/m}$; $\dot{Q}_{\text{conv}}/L = 1.6 \text{ kW/m}$
 6-129 $q_{\text{rad}} = -30.3 \text{ kW/m}^2$; $q_{\text{conv}} = -23.8 \text{ kW/m}^2$
 6-131 (i) 4.56 MW, (ii) 3.14 MW
 6-133 2220 kW/m^2
 6-135 $q_{\text{rad}} = -16.5 \text{ kW/m}^2$; $q_{\text{conv}} = -49.5 \text{ kW/m}^2$
 6-137 630 K
 6-139 $-5.48 \times 10^4 \text{ W/m}^2$

Chapter 7

- 7-1 $1.32 \times 10^4 \text{ W/m}^2 \text{ K}$; $1.18 \times 10^{-3} \text{ kg/m s}$
 7-3 $2781 \text{ W/m}^2 \text{ K}$; $5.79 \times 10^{-5} \text{ kg/s}$
 7-13 0.221
 7-15 (i) $1.552 \times 10^4 \text{ W/m}^2 \text{ K}$, $3.81 \times 10^{-4} \text{ kg/s}$, (ii) $1.015 \times 10^4 \text{ W/m}^2 \text{ K}$, $2.49 \times 10^{-3} \text{ kg/s}$
 7-17 $\dot{Q}/L = 4180 \text{ W/m}$; $\dot{m}/L = 3.71 \times 10^{-3} \text{ kg/m s}$
 7-19 $1840 \text{ W/m}^2 \text{ K}$; $7.59 \times 10^{-3} \text{ kg/m s}$
 7-25 $5.52 \times 10^4 \text{ W/m}^2$, $4.29 \times 10^{-3} \text{ kg/m s}$
 7-33 (ii) 369.2 K
 7-37 2.11 m
 7-39 15.8W , 50°C
 7-41 (i) 15.7 cm^2 , (ii) 390 K
 7-43 59.6 cm^2
 7-45 (i) 1.01 K, (ii) $2.93 \times 10^6 \text{ W/m}^2$, (iii) 440.9 K
 7-47 (i) $128 \text{ W/m}^2 \text{ K}$, (ii) $2.57 \times 10^4 \text{ W/m}^2$
 7-53 R-12: $2.41 \times 10^5 \text{ W/m}^2$, R-134a: $3.10 \times 10^5 \text{ W/m}^2$
 7-55 3.1 K/s
 7-57 $132.9 \text{ W/m}^2 \text{ K}$, 18.8 W
 7-59 (i) 200.1 W, 140.7 W, (ii) 200.1 W m
 7-63 (i) $3.84 \times 10^{-6} \text{ kg}$
 7-65 $294 \text{ W/m}^2 \text{ K}$
 7-67 640 W

Chapter 8

- 8-1 No
 8-3 19.4 kg/s
 8-5 2.80 W/m K
 8-7 370%
 8-11 135

8-13	2.22×10^{-2} kg/s; 28.4 m
8-15	(i) 321 K, (ii) 1.61, (iii) 23.8 m; 14.3 MW
8-17	(i) 1.40 m^2
8-19	6670 m^2
8-21	1260 W
8-23	0.331×10^{-3} kg/s
8-25	27.34°C
8-27	388 K
8-29	0.03185 kg/s; 8.53 m
8-31	(i) 373 K, (ii) 0.647, (iii) 1.81
8-33	(i) 619.6 K, (ii) 319 m^2
8-35	27.7°C
8-39	(i) 62.2 m^2 , (ii) 26.4 m^2 , (iii) 32.5 m^2 , (iv) 27.5 m^2
8-41	2.50 m
8-45	(i) 423 m^2 , (ii) impossible, (iii) 698 m^2 , (iv) 581 m^2
8-49	24.2°C
8-51	$3.47 \times 10^{-3} (\text{W}/\text{m}^2 \text{ K})^{-1}$
8-53	169.7 m^2
8-55	52
8-57	2.05 kg/s
8-59	(i) 35.6°C , (ii) 4.35 kg/s
8-61	70.3°C
8-65	(i) 2.338 kg/s, (ii) 26.5 m^2
8-67	101, 2.76 m
8-69	83.6 m^2
8-71	(i) No, (ii) 144 m^2 , (iii) 22.5%
8-73	Both fluids unmixed
8-75	26.3 m^2
8-77	$L = 3.624 \text{ m}$, $H = 0.607 \text{ m}$
8-79	598 Pa
8-81	$p = 1.2 \times 10^{-3} \text{ m}$, $L = 0.308 \text{ m}$, $H = 0.291 \text{ m}$
8-83	$A_f = 0.747 \text{ m}^2$, $L = 0.47 \text{ m}$, $H = 1.59 \text{ m}$
8-85	$H = 2.48 \text{ m}$, $L = 0.353 \text{ m}$
8-91	1.1 W
8-93	$H = 0.361 \text{ m}$, $L = 0.340 \text{ m}$
8-95	77.8 m^2 ; 37,500 \$/yr
8-97	12.6 m^2 ; 17,600 \$/yr
8-99	51.1 m^2 ; 78,460 \$/yr

Chapter 9

9-3	(i) 27.8 kg/kmol, (ii) 299 J/kg K, (iii) 127 ppm by mass
9-5	(i) 0.340, 0.646, 0.014; 68.9 kPa, 130.9 kPa, 2.84 kPa; 0.252, 0.746, 0.0012, (ii) 24.24 kg/kmol, 343 J/kg K, (iii) $0.984 \text{ kg}/\text{m}^3$, $4.06 \times 10^{-2} \text{ kmol}/\text{m}^3$, (iv) $0.248 \text{ kg}/\text{m}^3$, $0.734 \text{ kg}/\text{m}^3$, $0.0012 \text{ kg}/\text{m}^3$; $1.38 \times 10^{-2} \text{ kmol}/\text{m}^3$, $2.62 \times 10^{-2} \text{ kmol}/\text{m}^3$, $5.7 \times 10^{-4} \text{ kmol}/\text{m}^3$