UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2002/2003

Februari/Mac 2003

EKC 213 – Pemindahan Haba Proses

Masa : 3 jam

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Jawab mana-mana DUA soalan dari Bahagian A dan mana-mana DUA soalan dari Bahagian B.

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BAHAGIAN A Jawab mana-mana DUA soalan dari bahagian ini.
SECTION A Answer any TWO questions from this section.

1. [a] Terbitkan ungkapan untuk agihan suhu dalam suatu dinding satah yang mempunyai sumber haba yang teragih secara seragam. Satu muka dinding itu dikekalkan pada suhu T_1 manakala muka sebelahnya dikekalkan pada suhu T_2. Ketebalan dinding boleh dianggap sebagai 2L dan kemeresapan terma sama dengan sifar.

[5 markah]

[b] Haba dijanakan secara seragam di dalam sebuah plat keluli tahan karat yang mempunyai kekonduksian terma 20 W/mK. Ketebalan plat tersebut ialah 1.0 sm dan kadar penjanaan haba ialah 500 MW/m^3. Jika dua belah bahagian dikekalkan masing-masing pada 100 dan 200°C, kirakan suhu pada pusat plat tersebut.

[10 markah]

[c] Sirip lilitan bagi profil segiempat tepat dibina menggunakan keluli karbon dan dilekatkan pada tiub bulat yang dikekalkan pada 150°C. Garispusat tiub ialah 5 sm dan panjang sirip juga 5 sm dengan ketebalan 2 mm. Udara sekeliling dikekalkan pada 20 °C dan pekali pemindahan haba perolakan boleh diambil sebagai 100 W/m^2K dan pekali pemindahan haba pengaliran ialah 43 W/mK. Kirakan jumlah haba yang hilang dari sirip tersebut.

[10 markah]

1. [a] Derive on expression for the temperature distribution in a plane wall having uniformly distributed heat source. One face maintained at a temperature T_1 while the other face is maintained at a temperature T_2. The thickness of the wall may be taken as 2L and thermal diffusivity equal to zero.

[5 marks]

[b] Heat is generated uniformly in a stainless steel plate having thermal conductivity 20 W/mK. The thickness of the plate is 1.0 cm and the heat generation rate is 500Mw/m^3. If the two sides of the plate are maintained at 100 and 200°C, respectively, calculate the temperature at the centre of the plate.

[10 marks]

[c] A circumferential fin of rectangular profile is constructed of carbon steel and attached to a circular tube maintained at 150°C. The diameter of the tube is 5 cm and the length of the fin is also 5 cm with a thickness of 2 mm. The surrounding air is maintained at 20°C and the convection heat-transfer coefficient may be taken as 100W/m^2K and conduction heat-transfer coefficient is 43W/mK. Calculate the amount of heat lost from the fin.

[10 marks]

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2. Suatu simpang pengganding suhu yang boleh dianggap sebagai sfera, akan digunakan untuk mengukur suhu di dalam aliran gas. Pekali perolakan antara permukaan simpang dan gas diketahui sebagai $h = 400 W/m^2.K$ dan sifat-sifat simpul termofizikal ialah $K = 20$ W/m.K, Cp = 0.4 KJ/KgK dan $\rho = 8500.0$ Kg/m^3.

[a] Tentukan garispusat simpang yang diperlukan agar pengganding suhu itu mempunyai pemalar masa 1 saat.

[10 markah]

[b] Kira nombor Biot (Bi) simpang tersebut

[5 markah]

[c] Jika simpang berada pada 25°C dan diletakkan di dalam aliran gas 200°C, berapa lamakah yang akan diambil oleh simpang tersebut untuk mencapai 199°C.

[10 markah]

2. *A Thermocouple junction, which may be approximated as a sphere, is to be used for temperature measurement in a gas stream. The convection coefficient between the junction surface and the gas is known to be $h = 400 W/m^2.K$ and the junction thermo physical properties are $K = 20 W/m.K$, Cp = 0.4 KJ/KgK and $\rho = 8500.0$ Kg/m^3.*

[a] Determine the junction diameter needed for the thermocouple to have a time constant of one second.

[10 marks]

[b] Calculating Biot number (Bi) of the junction.

[5 marks]

[c] If the junction is at 25°C and is placed in a gas stream that is at 200°C, how long will it take for the junction to reach 199°C?

[10 marks]

3. [a] Udara pada 1 atm dan 0°C bertiup melalui silinder bergarispusat 4 sm yang dikekalkan pada suhu permukaan 54°C. Halaju udara ialah 25 m/s. Kira kehilangan haba dari silinder per unit panjang.

[5 markah]

[b] Udara pada 200 kPa bertiup melalui silinder bergarispusat 20 sm pada halaju 25 m/s dan suhu 10°C. Silinder tersebut dikekalkan pada suhu malar, 80°C. Kira pemindahan haba dan daya seret per unit panjang.

[10 markah]

...4/-

[c] Suatu wayar halus mempunyai garispusat 0.0254 mm dipanaskan oleh arus elektrik dan diletakkan secara mengufuk di dalam sebuah kebuk mengandungi helium pada 3 atm dan 10°C. Jika suhu permukaan wayar tersebut tidak melebihi 240°C, kira kuasa elektrik yang perlu dibekalkan per unit panjang.

[10 markah]

3. *[a] Air at 1 atm and zero°C blows across a 4cm diameter cylinder maintained at a surface temperature of 54°C. The air velocity is 25m/s. Calculate the heat loss from the cylinder per unit length.*

[5 marks]

[b] Air at 200 kpa blows across a 20 cm diameter cylinder at a velocity of 25 m/s and temperature of 10°C. The cylinder is maintained at a constant temperature of 80°C. Calculate the heat transfer and drag force per unit length.

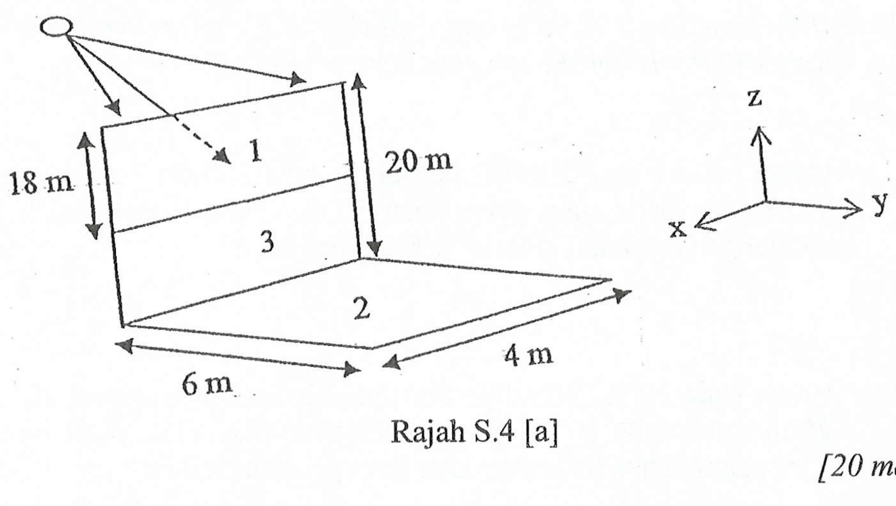
[10 marks]

[c] A fine wire having a diameter of 0.0254 mm is heated by an electric current and placed horizontally in a chamber containing helium at 3 atm and 10°C. If the surface temperature of the wire is not to exceed 240°C, calculate the electric power to be supplied per unit length.

[10 marks]

BAHAGIAN B Jawab mana-mana DUA soalan dari bahagian ini.
SECTION B Answer any TWO questions only from this section.

4. [a] Sekeping plat kaca (plat 1 daripada Rajah S. 4 [a]) diperbuat daripada bahan kuarza terlakur boleh menghantar 80% bagi semua radiasi terma tuju yang mempunyai panjang gelombang antara 0.2 dan 0.9 μm, menerima sumber radiasi pada suhu 5838°C. Anggapkan permukaan plat 2 ialah suatu jasad hitam, kira tenaga radiasi per unit luas (W/m^2) yang diterima oleh plat 2 dari plat 1. Pemalar Boltzman $\sigma = 5.669 \times 10^{-8}$ W/m^2K^4.



Rajah S.4 [a]

[20 markah]

[b] Anggapkan plat 3 hanya menerima tenaga dari plat 2, berapakah tenaga yang diterima oleh plat 3?

[5 markah]

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4. [a] *A glass plate (plate 1 from Figure Q.4 [a]) made from a fused quartz material which can transmit 80% of all incident thermal radiation of wavelength between 0.2 and 0.9 μm receives radiation source at temperature of 5838°C. Assuming that the surface of plate 2 is a blackbody, calculate the radiant energy per unit area (W/m²) received by plate 2 from plate 1. The Boltzman Constant, $\sigma = 5.669 \times 10^{-8}$ W/m²K⁴.*

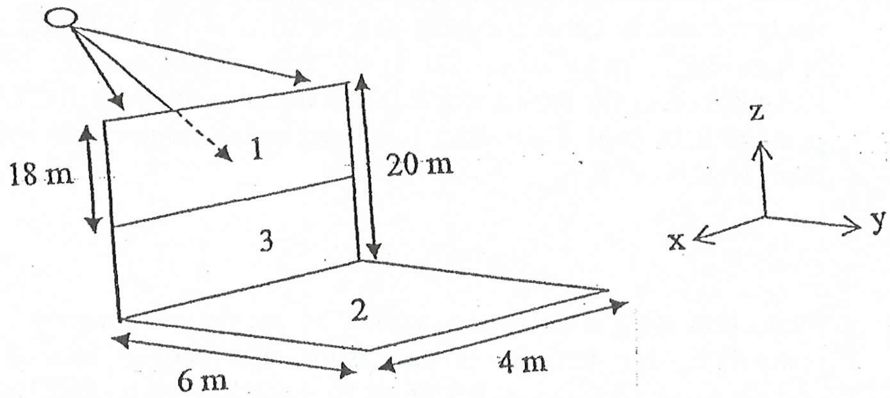

Figure Q.4 [a]

[20 marks]

[b] *Assuming plate 3 receives energy only from plate 2, how much energy is received by plate 3?*

[5 marks]

5. [a] Dua cakera selari mempunyai garispusat 50 sm dipisahkan sejauh 12.5 sm dan diletakkan di dalam bilik besar pada 300 K. Satu cakera (cakera 1) ialah pada 1000 K dan satu lagi cakera (cakera 2) dikekalkan pada suhu 500 K. Kedua-duanya mempunyai keberpancaran 0.8. Dengan menggunakan analog elektrik, kira kadar pemindahan haba untuk setiap cakera.

Diberi: $F_{1-2} = [X-(X^2 - 4)^{1/2}]/2$, di mana $X = (2R^2+1)/R^2$ dan $R = d/2x)$

[20 markah]

[b] Kira peratus pengurangan kadar pemindahan haba cakera 2 jika 4 perisai radiasi yang mempunyai keberpancaran yang sama diletakkan antara kedua-dua cakera. Anggapkan cakera itu adalah selari tak terhingga.

[5 markah]

5. [a] *Two parallel disks having diameters of 50 cm are separated by a distance of 12.5 cm and placed in a large room at 300K. One disk (disk 1) is at 1000K and the other (disk 2) is maintained at 500K. Both have emissivities of 0.8. Using an electrical analog, calculate the heat transfer rate for each disk.*

Given: $F_{1-2} = [X-(X^2 - 4)^{1/2}]/2$, *where* $X = (2R^2+1)/R^2$ *and* $R = d/2x)$

[20 marks]

[b] Calculate the percentage reduction of heat transfer rate of disk 2 if 4 radiation shields having similar emissivity are placed between the disks. Assume that the disks are infinitely parallel.

[5 marks]

6. [a] Suatu penukar haba aliran silang dengan kedua-dua bandalir tidak bercampur telah digunakan untuk memanaskan air (c_p = 4.181 kJ/kg K), daripada 40°C hingga 80°C, pada kadar 1.0 kg/s. Minyak enjin yang panas (c_p = 1.9 kJ/kg.K), mengalir pada kadar 2.6 kg/s masuk pada suhu 100°C. Kirakan luas penukar haba yang diperlukan pekali sekiranya pemindahan haba keseluruhan ialah 10 KW/m^2 K.

[13 markah]

[b] Suatu tiub mengufuk bergarispusat 2.54 sm dengan panjang 2 m dikekalkan pada 91°C dan terdedah kepada stim tepu pada 1 atm. Apakah kadar pemeluwapan (dalam g/s) sekiranya Nombor Reynolds ialah 1000?

(Diberi : $\mu = 2.97 \times 10^{-4}$kg/m.s, h_{fg} = 2255kJ/kg)

[12 markah]

6. [a] A crossflow heat exchanger with both fluids unmixed is used to heat water (c_p = 4.181 kJ/kg K), from 40 to 80°C, flowing at the rate of 1.0 kg/s. Hot engine oil (c_p = 1.9 kJ/kg.K), flowing at the rate of 2.6 kg/s, enters at 100 C. Calculate the required area of the heat exchanger if the overall heat transfer coefficient is 10 KW/m^2.K.

[13 marks]

[b] A 2.54 cm diameter horizontal tube with length of 2 m maintained at 91°C is exposed to saturated steam at 1 atm. What is the rate of condensation (in g/s) if Reynold Number of 1000?

(Given: $\mu = 2.97 \times 10^{-4}$kg/m.s, h_{fg} = 2255kJ/kg)

[12 marks]

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Lampiran

Heat transfer equation, graphs and table

1. $Nu = 0.0266\,(Re)^{0.805}\,(Pr)^{1/3}$ *for* $40x10^3 < Re < 40x10^4$

2. $$Nu = 0.3 + \frac{0.62\,(\mathrm{Re})^{1/2}\,(\mathrm{Pr})^{1/3}}{\left[1+(0.4/\mathrm{Pr})^{2/3}\right]^{1/4}}\left[1+\left(\frac{\mathrm{Re}}{282000}\right)^{5/8}\right]^{4/5}$$

   For $10^2 < Re < 10^7$

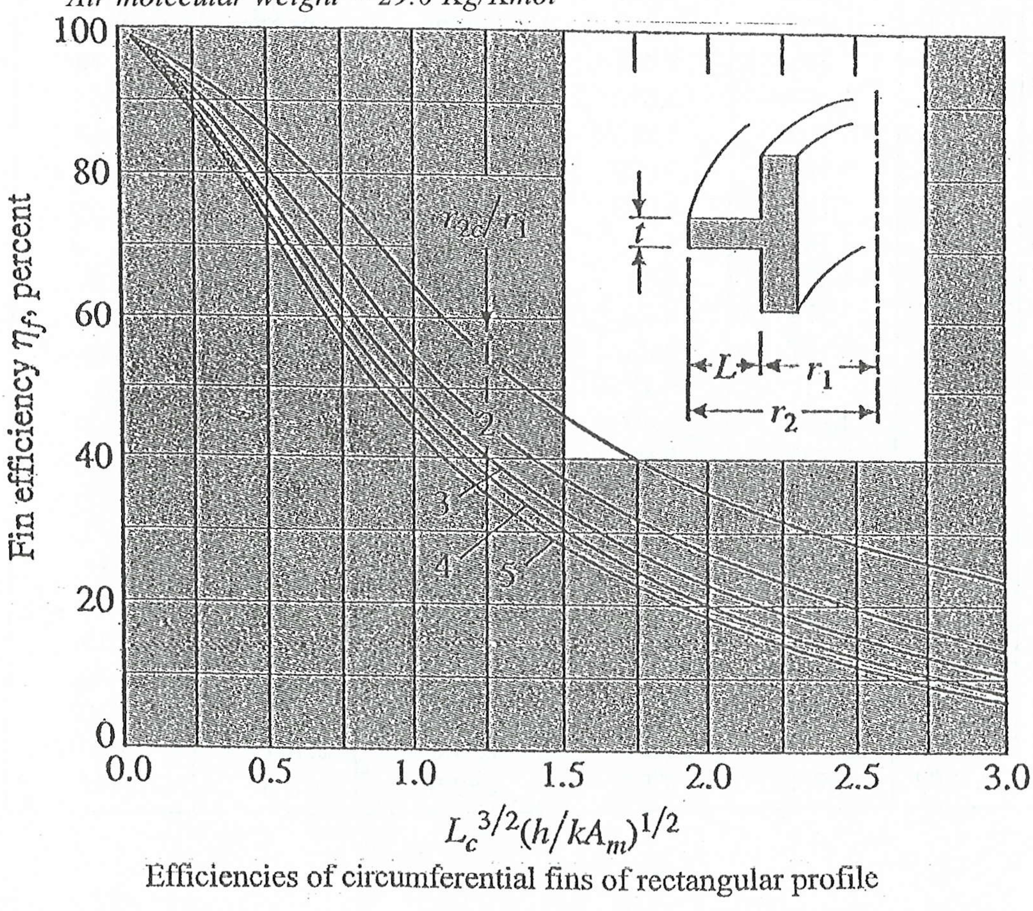
3. $$Nu = 0.36 + \frac{0.518\left[(\mathrm{Gr})(\mathrm{Pr})\right]^{1/4}}{\left[1+(0.559/\mathrm{Pr})^{9/16}\right]^{4/9}}$$

   For $10^{-6} < Gr\ Pr < 10^9$

   Where $$Gr\ Pr = \frac{9.8\,(\mathrm{B})(\mathrm{Tw} - \mathrm{T}\infty)\,\mathrm{d}^3\,\mathrm{Pr}}{\upsilon^2}$$

4. *Universal gas constant R = 8.314 KJ/Kmol.K*

   Air molecular weight = 29.0 Kg/Kmol



$L_c = L + \frac{t}{2}$

$r_{2c} = r_1 + L_c$

$A_m = t(r_{2c} - r_1)$

Efficiencies of circumferential fins of rectangular profile

Table 1 Properties of air at atmospheric pressure.

The values of μ, k, c_p, and Pr are not strongly pressure-dependent and may be used over a fairly wide range of pressures

T, K	ρ kg/m^3	c_p kJ/kg · °C	$\mu \times 10^5$ kg/m · s	$\nu \times 10^6$ m^2/s	k W/m · °C	$\alpha \times 10^4$ m^2/s	Pr
100	3.6010	1.0266	0.6924	1.923	0.009246	0.02501	0.770
150	2.3675	1.0099	1.0283	4.343	0.013735	0.05745	0.753
200	1.7684	1.0061	1.3289	7.490	0.01809	0.10165	0.739
250	1.4128	1.0053	1.5990	11.31	0.02227	0.15675	0.722
300	1.1774	1.0057	1.8462	15.69	0.02624	0.22160	0.708
350	0.9980	1.0090	2.075	20.76	0.03003	0.2983	0.697
400	0.8826	1.0140	2.286	25.90	0.03365	0.3760	0.689
450	0.7833	1.0207	2.484	31.71	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	37.90	0.04038	0.5564	0.680
550	0.6423	1.0392	2.848	44.34	0.04360	0.6532	0.680
600	0.5879	1.0551	3.018	51.34	0.04659	0.7512	0.680
650	0.5430	1.0635	3.177	58.51	0.04953	0.8578	0.682
700	0.5030	1.0752	3.332	66.25	0.05230	0.9672	0.684
750	0.4709	1.0856	3.481	73.91	0.05509	1.0774	0.686
800	0.4405	1.0978	3.625	82.29	0.05779	1.1951	0.689
850	0.4149	1.1095	3.765	90.75	0.06028	1.3097	0.692
900	0.3925	1.1212	3.899	99.3	0.06279	1.4271	0.696
950	0.3716	1.1321	4.023	108.2	0.06525	1.5510	0.699
1000	0.3524	1.1417	4.152	117.8	0.06752	1.6779	0.702
1100	0.3204	1.160	4.44	138.6	0.0732	1.969	0.704
1200	0.2947	1.179	4.69	159.1	0.0782	2.251	0.707
1300	0.2707	1.197	4.93	182.1	0.0837	2.583	0.705
1400	0.2515	1.214	5.17	205.5	0.0891	2.920	0.705
1500	0.2355	1.230	5.40	229.1	0.0946	3.262	0.705
1600	0.2211	1.248	5.63	254.5	0.100	3.609	0.705
1700	0.2082	1.267	5.85	280.5	0.105	3.977	0.705
1800	0.1970	1.287	6.07	308.1	0.111	4.379	0.704
1900	0.1858	1.309	6.29	338.5	0.117	4.811	0.704
2000	0.1762	1.338	6.50	369.0	0.124	5.260	0.702
2100	0.1682	1.372	6.72	399.6	0.131	5.715	0.700
2200	0.1602	1.419	6.93	432.6	0.139	6.120	0.707
2300	0.1538	1.482	7.14	464.0	0.149	6.540	0.710
2400	0.1458	1.574	7.35	504.0	0.161	7.020	0.718
2500	0.1394	1.688	7.57	543.5	0.175	7.441	0.730

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Table 2 Properties of gases at atmospheric pressure

Values of μ, k, c_p, and Pr are not strongly pressure-dependent for He, H_2, O_2, and N_2 and may be used over a fairly wide range of pressures

T, K	ρ kg/m^3	c_p kJ/kg · °C	μ, kg/m · s	ν, m^2/s	k W/m · °C	α, m^2/s	Pr
				Helium			
144	0.3379	5.200	125.5×10^{-7}	37.11×10^{-6}	0.0928	0.5275×10^{-4}	0.70
200	0.2435	5.200	156.6	64.38	0.1177	0.9288	0.694
255	0.1906	5.200	181.7	95.50	0.1357	1.3675	0.70
366	0.13280	5.200	230.5	173.6	0.1691	2.449	0.71
477	0.10204	5.200	275.0	269.3	0.197	3.716	0.72
589	0.08282	5.200	311.3	375.8	0.225	5.215	0.72
700	0.07032	5.200	347.5	494.2	0.251	6.661	0.72
800	0.06023	5.200	381.7	634.1	0.275	8.774	0.72
				Hydrogen			
150	0.16371	12.602	5.595×10^{-6}	34.18×10^{-6}	0.0981	0.475×10^{-4}	0.718
200	0.12270	13.540	6.813	55.53	0.1282	0.772	0.719
250	0.09819	14.059	7.919	80.64	0.1561	1.130	0.713
300	0.08185	14.314	8.963	109.5	0.182	1.554	0.706
350	0.07016	14.436	9.954	141.9	0.206	2.031	0.697
400	0.06135	14.491	10.864	177.1	0.228	2.568	0.690
450	0.05462	14.499	11.779	215.6	0.251	3.164	0.682
500	0.04918	14.507	12.636	257.0	0.272	3.817	0.675
550	0.04469	14.532	13.475	301.6	0.292	4.516	0.668
600	0.04085	14.537	14.285	349.7	0.315	5.306	0.664
700	0.03492	14.574	15.89	455.1	0.351	6.903	0.659
800	0.03060	14.675	17.40	569	0.384	8.563	0.664
900	0.02723	14.821	18.78	690	0.412	10.217	0.676
				Oxygen			
150	2.6190	0.9178	11.490×10^{-6}	4.387×10^{-6}	0.01367	0.05688×10^{-4}	0.773
200	1.9559	0.9131	14.850	7.593	0.01824	0.10214	0.745
250	1.5618	0.9157	17.87	11.45	0.02259	0.15794	0.725
300	1.3007	0.9203	20.63	15.86	0.02676	0.22353	0.709
350	1.1133	0.9291	23.16	20.80	0.03070	0.2968	0.702
400	0.9755	0.9420	25.54	26.18	0.03461	0.3768	0.695
450	0.8682	0.9567	27.77	31.99	0.03828	0.4609	0.694
500	0.7801	0.9722	29.91	38.34	0.04173	0.5502	0.697
550	0.7096	0.9881	31.97	45.05	0.04517	0.641	0.700
				Nitrogen			
200	1.7108	1.0429	12.947×10^{-6}	7.568×10^{-6}	0.01824	0.10224×10^{-4}	0.747
300	1.1421	1.0408	17.84	15.63	0.02620	0.22044	0.713
400	0.8538	1.0459	21.98	25.74	0.03335	0.3734	0.691
500	0.6824	1.0555	25.70	37.66	0.03984	0.5530	0.684
600	0.5687	1.0756	29.11	51.19	0.04580	0.7486	0.686
700	0.4934	1.0969	32.13	65.13	0.05123	0.9466	0.691
800	0.4277	1.1225	34.84	81.46	0.05609	1.1685	0.700
900	0.3796	1.1464	37.49	91.06	0.06070	1.3946	0.711
1000	0.3412	1.1677	40.00	117.2	0.06475	1.6250	0.724
1100	0.3108	1.1857	42.28	136.0	0.06850	1.8571	0.736
1200	0.2851	1.2037	44.50	156.1	0.07184	2.0932	0.748

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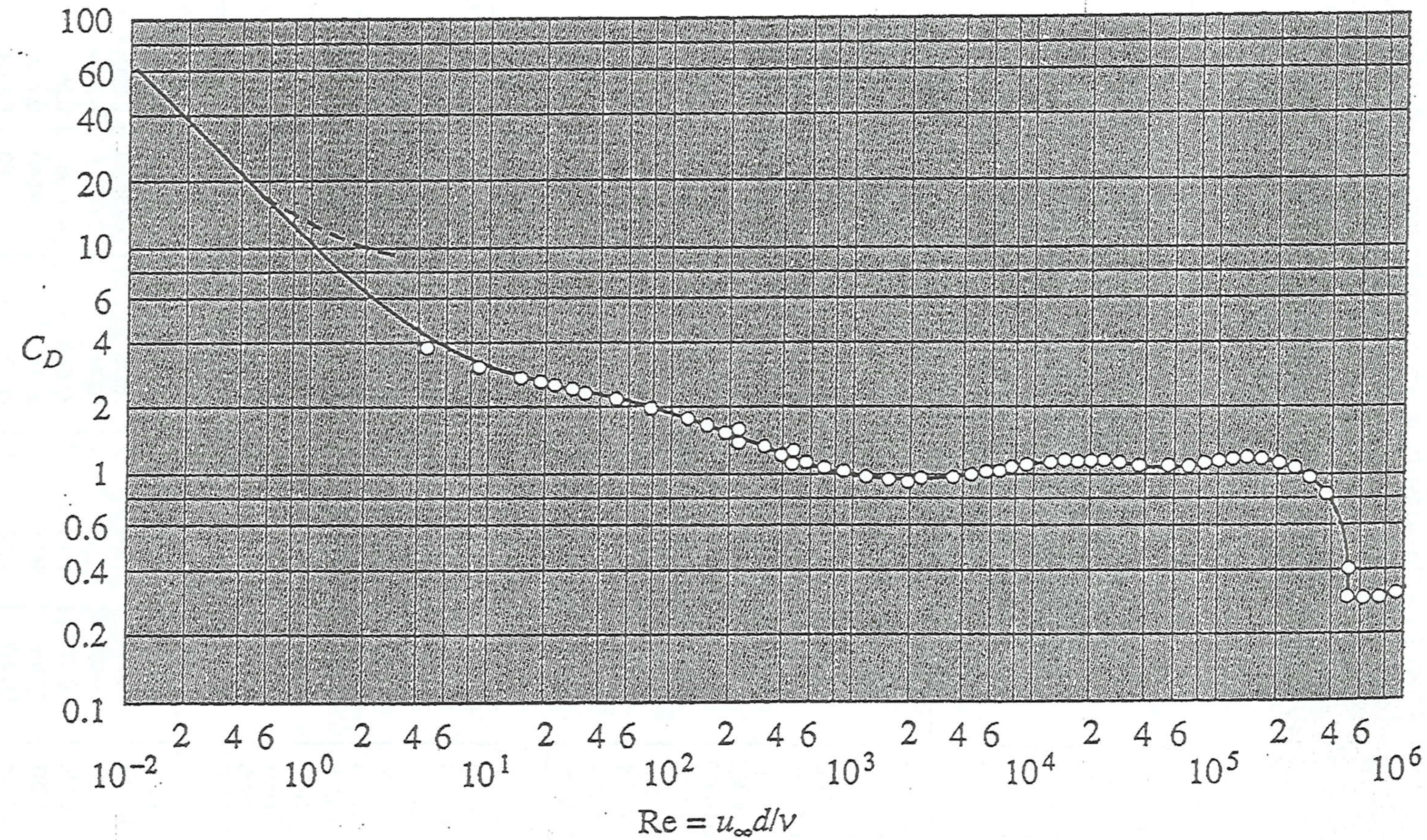

Drag coefficient for circular cylinders as a function of the Reynolds number.

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Table 3 Radiation Functions

λT μm K	$E_{b\lambda}/T^5$ $\frac{W}{m^2\,K^5\,\mu m}$ $\times 10^{11}$	$\frac{E_{b_{0-\lambda T}}}{\sigma T^4}$
555.6	0.400×10^{-5}	0.170×10^{-7}
666.7	0.120×10^{-3}	0.756×10^{-6}
777.8	0.00122	0.106×10^{-4}
888.9	0.00630	0.738×10^{-4}
1 000.0	0.02111	0.321×10^{-3}
1 111.1	0.05254	0.00101
1 222.2	0.10587	0.00252
1 333.3	0.18275	0.00531
1 444.4	0.28091	0.00983
1 555.6	0.39505	0.01643
1 666.7	0.51841	0.02537
1 777.8	0.64404	0.03677
1 888.9	0.76578	0.05059
2 000.0	0.87878	0.06672
2 111.1	0.97963	0.08496
2 222.2	1.0663	0.10503
2 333.3	1.1378	0.12665
2 444.4	1.1942	0.14953
2 555.6	1.2361	0.17337
2 666.7	1.2645	0.19789
2 777.8	1.2808	0.22285
2 888.9	1.2864	0.24803
3 000.0	1.2827	0.27322
3 111.1	1.2713	0.29825
3 222.2	1.2532	0.32300
3 333.3	1.2299	0.34734
3 444.4	1.2023	0.37118
3 555.6	1.1714	0.39445
3 666.7	1.1380	0.41708
3 777.8	1.1029	0.43905
3 888.9	1.0665	0.46031
4 000.0	1.0295	0.48085
4 111.1	0.99221	0.50066
4 222.2	0.95499	0.51974
4 333.3	0.91813	0.53809
4 444.4	0.88184	0.55573
4 555.6	0.84629	0.57267
4 666.7	0.81163	0.58891
4 777.8	0.77796	0.60449
4 888.9	0.74534	0.61941
5 000.0	0.71383	0.63371
5 111.1	0.68346	0.64740
5 222.2	0.65423	0.66051
5 333.3	0.62617	0.67305
5 444.4	0.59925	0.68506
5 555.6	0.57346	0.69655

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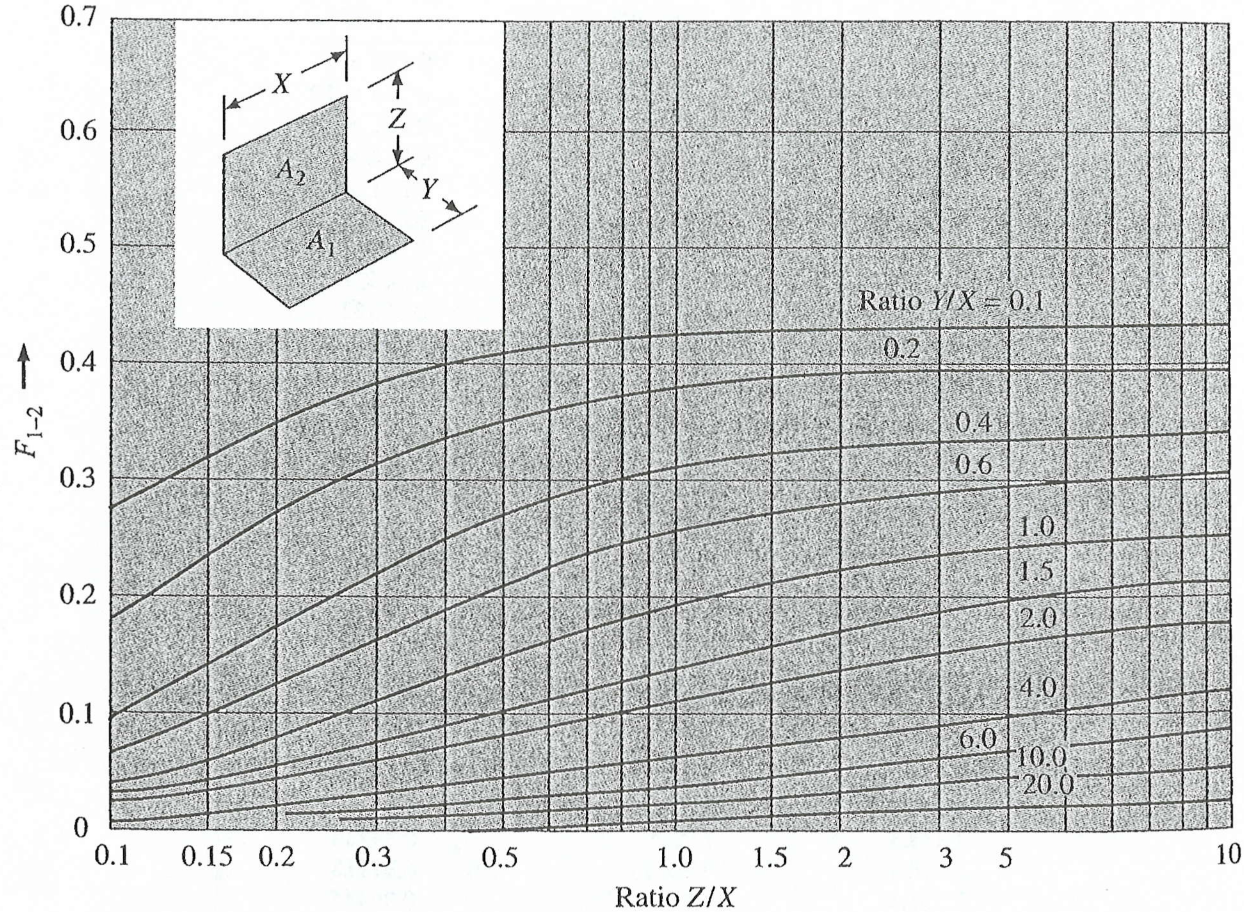
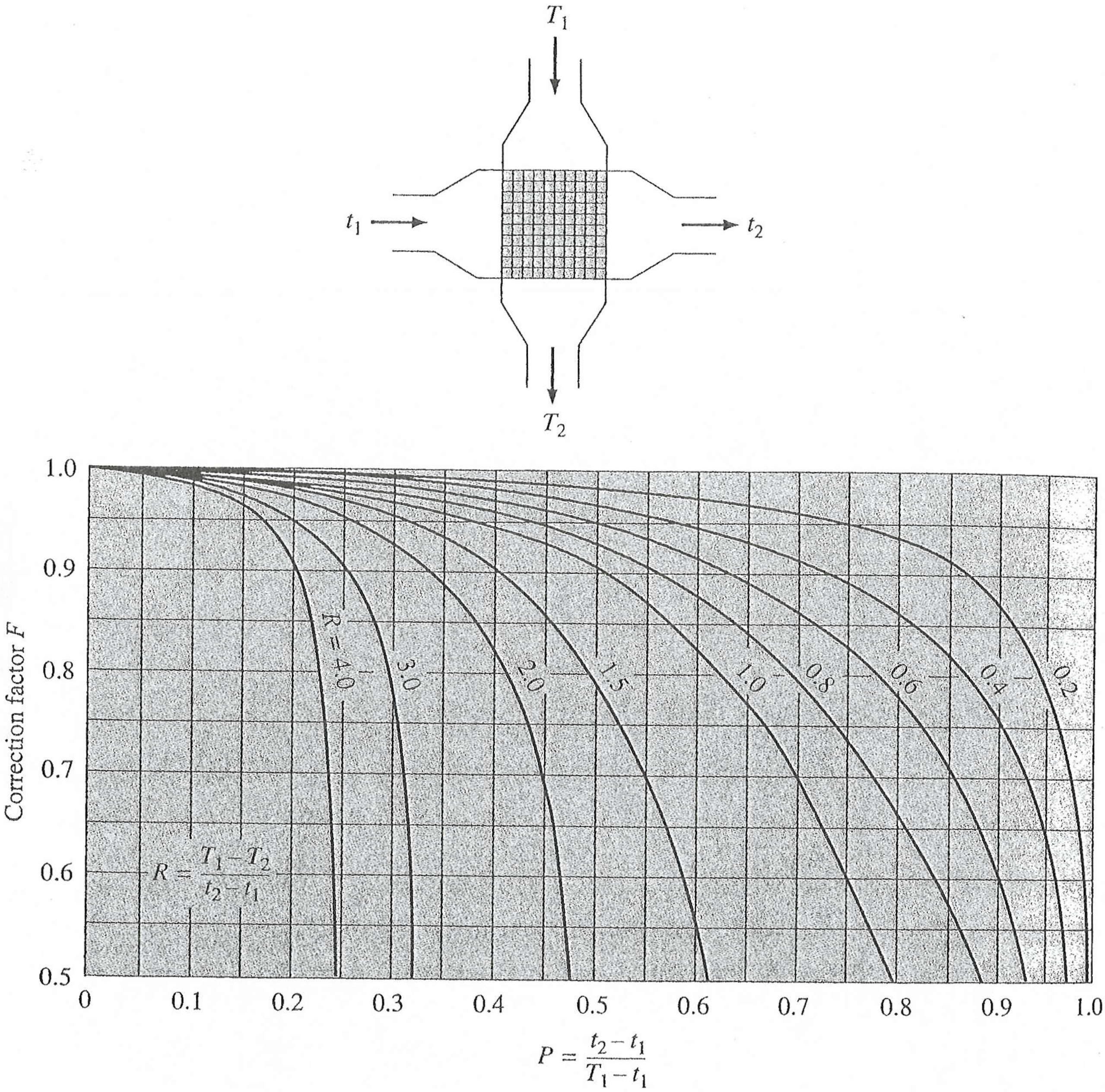


Radiation shape factor for radiation between perpendicular rectangles with a common edge.

...7/-



Correction-factor plot for single-pass cross-flow exchanger, both fluids unmixed.