INSTRUCTION:

This section consists of **FOUR (4)** structured questions. Answer **ALL** questions.

ARAHAN:

*Bahagian ini mengandungi **EMPAT (4)** soalan berstruktur. Jawab **SEMUA** soalan.*

QUESTION 1

SOALAN 1

CLO1 C1 (a) Heat transfer is the form of energy that can be transferred from one system to another system as a result of temperature difference.
Pemindahan haba adalah satu bentuk tenaga yang boleh dipindahkan dari satu sistem ke.sistem lain akibat dari perbezaan suhu.

i. List **THREE (3)** mode of heat transfer.
*Senaraikan **TIGA (3)** mod pemindahan haba.*

[3 Marks]
[3 Markah]

ii. Select **TWO (2)** mode of heat transfer and write down its formula.
*Pilih **DUA (2)** elemen dan nyatakan formulanya.*

[2 Marks]
[2 Markah]

CLO1 C2 (b) Explain the **THREE (3)** mode of heat transfer with definition and examples.
*Jelaskan **TIGA (3)** mod pemindahan haba dengan definisi dan contoh.*

[8 Marks]
[8 Markah]

CLO2 C3

(c) Consider a 1.2 m high and 2.5 m wide double pane window consisting of two 3.25 mm thick layers of glass (k = 0.78 W/m·°C) that is separated by a 12.5 mm wide stagnant air space (k = 0.026 W/m·°C). Take the convection heat transfer coefficient on the inner and outer surfaces of the window to be h_1 = 10 W/m^2·°C and h_2 = 25 W/m^2·°C as shown in **Figure 1(c)**, and disregard any heat transfer by radiation. Temperature of indoors is maintained at 20°C while the temperature of the outdoors is - 10°C. Calculate thermal resistance for each layer and heat transfer rate.

Pertimbangkan tingkap dua panel 1.2 m tinggi dan 2.5 m lebar yang terdiri daripada dua lapisan tebal kaca 3.25 mm (k = 0.78 W/m·°C) dipisahkan oleh ruang udara tetap 12.5mm (k = 0.026 W/m·°C). Pekali pemindahan haba perolakan bagi permukaan dalaman dan luaran ialah h_1 = 10 W/m^2·°C and h_2 = 25 W/m^2·°C seperti yang ditunjukkan dalam ***Gambarajah 1(c)****, dan abaikan sebarang pemindahan haba oleh radiasi. Suhu dalam bilik kekal pada 20°C manakala suhu di luar adalah -10 ° C. Kirakan rintangan haba bagi setiap lapisan dan kadar pemindahan haba.*

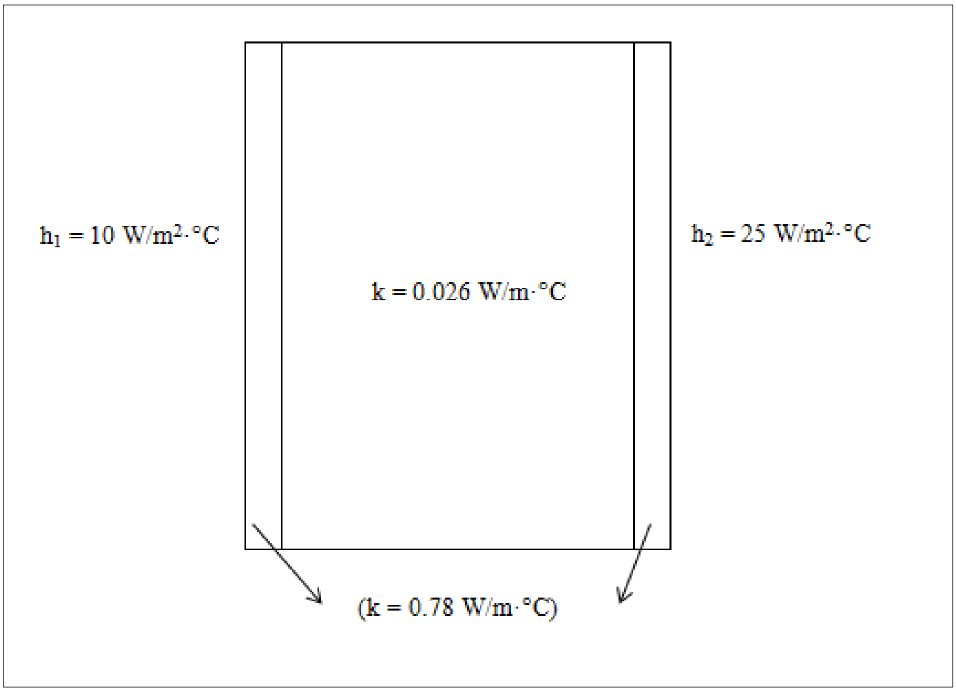

Figure 1(c)

Gambarajah 1(c)

[12 Marks]

[12 Markah]

QUESTION 2
SOALAN 2

CLO1 C2

(a) Heat transfer through a liquid or gas can be by conduction or convection depending on the presence of any bulk fluid motion.
Pemindahan haba melalui cecair atau gas boleh terjadi melalui konduksi atau perolakan bergantung kepada kehadiran pergerakan pukal cecair.

i. Convection heat transfer is depending on the fluid properties. Describe **THREE (3)** types of fluid flow in convection heat transfer.
*Pemindahan haba perolakan bergantung kepada sifat cecair. Senaraikan **TIGA (3)** jenis aliran cecair dalam pemindahan haba perolakan.*

[3 Marks]
[3 Markah]

ii. Describe **ONE (1)** similarity and difference between heat conduction and heat convection.
*Terangkan **SATU (1)** persamaan dan perbezaan di antara haba konduksi dan haba perolakan.*

[2 Marks]
[2 Markah]

CLO2
C3

(b) During a cold winter day, wind at 55km/h blowing parallel to a 4-m-high and 10-m-long wall of a house. If the air outside is at 5°C and the surface temperature of the wall is 12°C as shown in **Figure 2(b)**, determine the rate of heat loss from that wall by convection.
Semasa musim sejuk, angin pada 55km/j bertiup selari dengan dinding rumah 4-m-tinggi dan 10-m-panjang. Jika udara di luar berada pada 5 ° C dan suhu permukaan dinding adalah 12 ° C seperti yang ditunjukkan dalam ***Gambarajah 2(b)****, tentukan kadar kehilangan haba dari dinding itu dengan perolakan.*

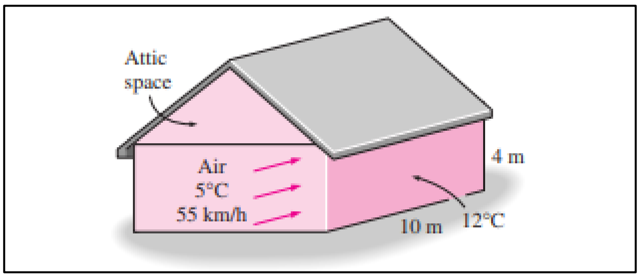

Figure 2(b)
Gambarajah 2(b)

[10 Marks]
[10 Markah]

CLO2
C4

(c) Mercury at 25ºC flows over a 3m-long and 2-m wide flat plate maintained at 75 ºC with a velocity of 0.8m/s. Determine the rate of heat transfer from the entire plate.
Merkuri pada 25ºC mengalir di atas plat rata 3m panjang dan 2m lebar yang dikekalkan pada 75ºC dengan halaju 0.8m/s. Tentukan kadar pemindahan haba dari keseluruhan plat.

[10 Marks]
[10 Markah]

QUESTION

SOALAN 3

CLO1 C2

(a) Heat radiation is different from heat conduction and heat convection due to the radiation characteristics. Identify **SEVEN (7**) examples of heat radiation.

Haba sinaran adalah berbeza daripada haba konduksi dan haba perolakan disebabkan oleh ciri-ciri sinaran. Senaraikan ***TUJUH (7)*** *contoh haba sinaran.*

[7 Marks]

[7 Markah]

CLO2 C3

(b) The spectral emissivity function of an opaque surface at 1000 K as shown in **Figure 3(b)**. Determine the average emissivity of the surface and the rate of radiation emission from the surface, in W/m^2.

Fungsi pelepasan spektrum bagi permukaan legap pada 1000 K seperti yang ditunjukkan dalam ***Gambarajah 3(b)****. Tentukan purata pelepasan permukaan dan kadar pelepasan sinaran dari permukaan, dalam* W/m^2.

$$\varepsilon_\lambda = \begin{cases} \varepsilon_1 = 0.4, & 0 \leq \lambda < 2\ \mu m \\ \varepsilon_2 = 0.7, & 2\ \mu m \leq \lambda < 6\ \mu m \\ \varepsilon_3 = 0.3, & 6\ \mu m \leq \lambda < \infty \end{cases}$$

Figure 3(b)

Gambarajah 3(b)

[10 Marks]

[10 Markah]

CLO2 C4

(c) Explain **THREE (3)** properties of radiation with definition and complete illustration in semitransparent material.

Terangkan ***TIGA (3)*** *sifat sinaran dengan definisi dan ilustrasi lengkap dalam bahan separa lutsinar.*

[8 marks]

[8 markah]

QUESTION 4

SOALAN 4

CLO1 C2

(a) Identify **FIVE (5)** selection factors need to be considered by technician/engineer before choosing a proper heat exchanger.

*Senaraikan **LIMA (5)** faktor pemilihan yang perlu dipertimbangkan oleh juruteknik / jurutera sebelum memilih penukar haba yang sesuai.*

[5 Marks]

[5 Markah]

CLO2 C3

(b) A double-pipe counter-flow heat exchanger is to cool ethylene glycol (Cp = 2560 J/kg· °C) flowing at a rate of 3.5 kg/s from 80°C to 40°C by water (Cp = 4180 J/kg · °C) that enters at 20°C and leaves at 55°C. The overall heat transfer coefficient based on the inner surface area of the tube is 250 W/m^2 · °C. Determine the rate of heat transfer.

Penukar haba aliran bertentangan paip berganda adalah untuk menyejukkan etilena glikol (Cp = 2560 J / kg · ° C) yang mengalir pada kadar 3.5 kg / s dari 80 ° C hingga 40 ° C dengan menggunakan air (Cp = 4180 J / kg · ° C) yang memasuki pada suhu 20 ° C dan keluar pada suhu 55 ° C. Pekali pemindahan haba keseluruhan berdasarkan kawasan permukaan dalam tiub adalah 250 W/m^2·°C. Tentukan kadar pemindahan haba.

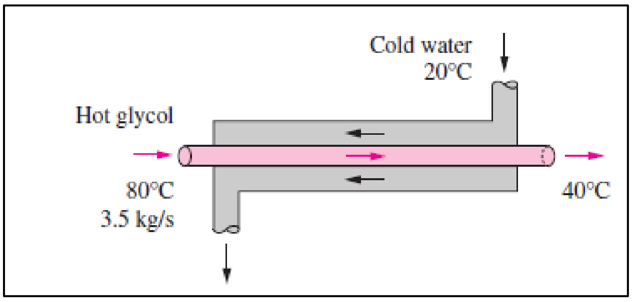

Figure 4(b)

Gambarajah 4(b)

[10 marks]

[10 markah]

CLO2
C4

(c) Engine oil (Cp = 2100 J/kg · °C) is to be heated from 20°C to 60°C at a rate of 0.3 kg/s in a 2-cm-diameter thin walled copper tube by condensing steam outside at a temperature of 130°C (hfg = 2174 kJ/kg) as shown in Figure 4(c). For an overall heat transfer coefficient of 650 W/m^2 · °C, determine the rate of heat transfer and the length of the tube required to achieve it.

Minyak enjin (Cp = 2100 J / kg · ° C) hendaklah dipanaskan dari 20 ° C hingga 60°C pada kadar 0.3 kg/s dalam tiub tembaga berdinding nipis berdiameter 2 cm dengan menampung wap di luar pada suhu 130°C (hfg = 2174 kJ / kg) seperti dalam Gambarajah 4(c). Untuk pekali pemindahan haba keseluruhan 650 W/m^2. ° C, tentukan kadar pemindahan haba dan panjang tiub yang diperlukan untuk mencapainya.

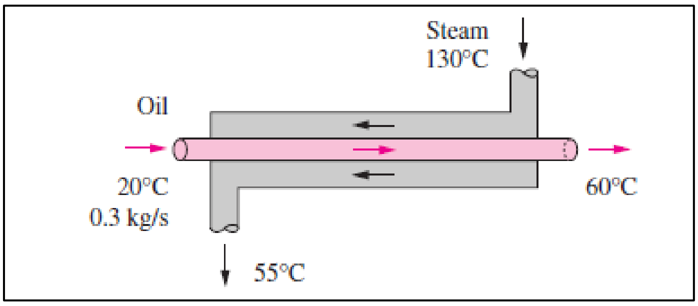

Figure 4(c)

Gambarajah 4(c)

[10 marks]

[10 markah]

SOALAN TAMAT

Formula list / *Senarai formula*

CONDUCTION

The elementary thermal resistance relations:

Conduction resistance (plane wall): $R_{\text{wall}} = \dfrac{L}{kA}$

Conduction resistance (cylinder): $R_{\text{cyl}} = \dfrac{\ln(r_2/r_1)}{2\pi Lk}$

Conduction resistance (sphere): $R_{\text{sph}} = \dfrac{r_2 - r_1}{4\pi r_1 r_2 k}$

Convection resistance: $R_{\text{conv}} = \dfrac{1}{hA}$

CONVECTION

The average friction coefficient relations for flow over a flat plate:

Laminar: $C_f = \dfrac{1.328}{\text{Re}_L^{1/2}}$ $\quad \text{Re}_L < 5 \times 10^5$

Turbulent: $C_f = \dfrac{0.074}{\text{Re}_L^{1/5}}$ $\quad 5 \times 10^5 \le \text{Re}_L \le 10^7$

Combined: $C_f = \dfrac{0.074}{\text{Re}_L^{1/5}} - \dfrac{1742}{\text{Re}_L}$ $\quad 5 \times 10^5 \le \text{Re}_L \le 10^7$

Rough surface, turbulent: $C_f = \left(1.89 - 1.62 \log \dfrac{\varepsilon}{L}\right)^{-2.5}$

The average Nusselt number relations for flow over a flat plate:

Laminar: $\text{Nu} = \dfrac{hL}{k} = 0.664\ \text{Re}_L^{0.5}\ \text{Pr}^{1/3}$ $\quad \text{Re}_L < 5 \times 10^5$

Turbulent:

$$\text{Nu} = \frac{hL}{k} = 0.037\ \text{Re}_L^{0.8}\ \text{Pr}^{1/3} \qquad \begin{array}{l} 0.6 \le \text{Pr} \le 60 \\ 5 \times 10^5 \le \text{Re}_L \le 10^7 \end{array}$$

Combined:

$$\text{Nu} = \frac{hL}{k} = (0.037\ \text{Re}_L^{0.8} - 871)\ \text{Pr}^{1/3}, \qquad \begin{array}{l} 0.6 \le \text{Pr} \le 60 \\ 5 \times 10^5 \le \text{Re}_L \le 10^7 \end{array}$$

The average Nusselt number for cross flow over a cylinder and sphere:

$$\text{Nu}_{\text{cyl}} = \frac{hD}{k} = 0.3 + \frac{0.62\ \text{Re}^{1/2}\ \text{Pr}^{1/3}}{[1 + (0.4/\text{Pr})^{2/3}]^{1/4}} \left[1 + \left(\frac{\text{Re}}{282{,}000}\right)^{5/8}\right]^{4/5}$$

which is valid for $\text{Re Pr} > 0.2$, and

$$\text{Nu}_{\text{sph}} = \frac{hD}{k} = 2 + [0.4\ \text{Re}^{1/2} + 0.06\ \text{Re}^{2/3}]\text{Pr}^{0.4}\left(\frac{\mu_\infty}{\mu_s}\right)^{1/4}$$

which is valid for $3.5 \le \text{Re} \le 80{,}000$ and $0.7 \le \text{Pr} \le 380$

RADIATION

Stefan–Boltzmann law: $E_b(T) = \sigma T^4$; $\sigma = 5.670 \times 10^{-8}$ W/m²·K⁴

Spectral blackbody emmisive power;

$$E_{b\lambda}(\lambda, T) = \frac{C_1}{\lambda^5[\exp(C_2/\lambda T) - 1]} \qquad (\mathrm{W/m^2 \cdot \mu m})$$

where

$$C_1 = 2\pi h c_0^2 = 3.742 \times 10^8 \ \mathrm{W \cdot \mu m^4/m^2}$$
$$C_2 = h c_0/k = 1.439 \times 10^4 \ \mathrm{\mu m \cdot K}$$

Wien's displacement law:

$$(\lambda T)_{\text{max power}} = 2897.8 \ \mathrm{\mu m \cdot K}$$

HEAT EXCHANGER

Overall heat transfer coefficient U or a total thermal resistance R, expressed as:

$$\frac{1}{UA_s} = \frac{1}{U_i A_i} = \frac{1}{U_o A_o} = R = \frac{1}{h_i A_i} + R_{\text{wall}} + \frac{1}{h_o A_o}$$

The effects of fouling on both the inner and the outer surfaces of the tubes of a heat exchanger can be accounted for by:

$$\frac{1}{UA_s} = \frac{1}{U_i A_i} = \frac{1}{U_o A_o} = R$$
$$= \frac{1}{h_i A_i} + \frac{R_{f,i}}{A_i} + \frac{\ln(D_o/D_i)}{2\pi k L} + \frac{R_{f,o}}{A_o} + \frac{1}{h_o A_o}$$

LMTD method, the rate of heat transfer

$$\dot{Q} = UA_s \Delta T_{\text{lm}}$$

where

$$\Delta T_{\text{lm}} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)}$$

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m³	Specific Heat c_p, J/kg·K	Thermal Conductivity k, W/m·K	Thermal Diffusivity α, m²/s	Dynamic Viscosity μ, kg/m·s	Kinematic Viscosity ν, m²/s	Prandtl Number Pr
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	0.7246
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-5}	5.837×10^{-6}	0.7263
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	0.7440
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	0.7436
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	0.7425
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	0.7408
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	0.7255
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	0.7241
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	0.7228
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	0.7202
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	0.7177
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	0.7154
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}	0.7132
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}	0.7111
120	0.8977	1011	0.03235	3.565×10^{-5}	2.264×10^{-5}	2.522×10^{-5}	0.7073
140	0.8542	1013	0.03374	3.898×10^{-5}	2.345×10^{-5}	2.745×10^{-5}	0.7041
160	0.8148	1016	0.03511	4.241×10^{-5}	2.420×10^{-5}	2.975×10^{-5}	0.7014
180	0.7788	1019	0.03646	4.593×10^{-5}	2.504×10^{-5}	3.212×10^{-5}	0.6992
200	0.7459	1023	0.03779	4.954×10^{-5}	2.577×10^{-5}	3.455×10^{-5}	0.6974
250	0.6746	1033	0.04104	5.890×10^{-5}	2.760×10^{-5}	4.091×10^{-5}	0.6946
300	0.6158	1044	0.04418	6.871×10^{-5}	2.934×10^{-5}	4.765×10^{-5}	0.6935
350	0.5664	1056	0.04721	7.892×10^{-5}	3.101×10^{-5}	5.475×10^{-5}	0.6937
400	0.5243	1069	0.05015	8.951×10^{-5}	3.261×10^{-5}	6.219×10^{-5}	0.6948
450	0.4880	1081	0.05298	1.004×10^{-4}	3.415×10^{-5}	6.997×10^{-5}	0.6965
500	0.4565	1093	0.05572	1.117×10^{-4}	3.563×10^{-5}	7.806×10^{-5}	0.6986
600	0.4042	1115	0.06093	1.352×10^{-4}	3.846×10^{-5}	9.515×10^{-5}	0.7037
700	0.3627	1135	0.06581	1.598×10^{-4}	4.111×10^{-5}	1.133×10^{-4}	0.7092
800	0.3289	1153	0.07037	1.855×10^{-4}	4.362×10^{-5}	1.326×10^{-4}	0.7149
900	0.3008	1169	0.07465	2.122×10^{-4}	4.600×10^{-5}	1.529×10^{-4}	0.7206
1000	0.2772	1184	0.07868	2.398×10^{-4}	4.826×10^{-5}	1.741×10^{-4}	0.7260
1500	0.1990	1234	0.09599	3.908×10^{-4}	5.817×10^{-5}	2.922×10^{-4}	0.7478
2000	0.1553	1264	0.11113	5.664×10^{-4}	6.630×10^{-5}	4.270×10^{-4}	0.7539

Note: For ideal gases, the properties c_p, k, μ, and Pr are independent of pressure. The properties ρ, ν, and α at a pressure P (in atm) other than 1 atm are determined by multiplying the values of ρ at the given temperature by P and by dividing ν and α by P.

Source: Data generated from the EES software developed by S. A. Klein and F. L. Alvarado. Original sources: Keenan, Chao, Keyes, Gas Tables, Wiley, 1984; and Thermophysical Properties of Matter. Vol. 3: Thermal Conductivity, Y. S. Touloukian, P. E. Liley, S. C. Saxena, Vol. 11: Viscosity, Y. S. Touloukian, S. C. Saxena, and P. Hestermans, IFI/Plenun, NY, 1970, ISBN 0-306067020-8.

Properties of liquid metals

Temp. T, °C	Density ρ, kg/m³	Specific Heat c_p, J/kg·K	Thermal Conductivity k, W/m·K	Thermal Diffusivity α, m²/s	Dynamic Viscosity μ, kg/m·s	Kinematic Viscosity ν, m²/s	Prandtl Number Pr	Volume Expansion Coeff. β, 1/K
				Mercury (Hg) Melting Point: −39°C				
0	13595	140.4	8.18200	4.287×10^{-6}	1.687×10^{-3}	1.241×10^{-7}	0.0289	1.810×10^{-4}
25	13534	139.4	8.51533	4.514×10^{-6}	1.534×10^{-3}	1.133×10^{-7}	0.0251	1.810×10^{-4}
50	13473	138.6	8.83632	4.734×10^{-6}	1.423×10^{-3}	1.056×10^{-7}	0.0223	1.810×10^{-4}
75	13412	137.8	9.15632	4.956×10^{-6}	1.316×10^{-3}	9.819×10^{-8}	0.0198	1.810×10^{-4}
100	13351	137.1	9.46706	5.170×10^{-6}	1.245×10^{-3}	9.326×10^{-8}	0.0180	1.810×10^{-4}
150	13231	136.1	10.07780	5.595×10^{-6}	1.126×10^{-3}	8.514×10^{-8}	0.0152	1.810×10^{-4}
200	13112	135.5	10.65465	5.996×10^{-6}	1.043×10^{-3}	7.959×10^{-8}	0.0133	1.815×10^{-4}
250	12993	135.3	11.18150	6.363×10^{-6}	9.820×10^{-4}	7.558×10^{-8}	0.0119	1.829×10^{-4}
300	12873	135.3	11.68150	6.705×10^{-6}	9.336×10^{-4}	7.252×10^{-8}	0.0108	1.854×10^{-4}
				Bismuth (Bi) Melting Point: 271°C				
350	9969	146.0	16.28	1.118×10^{-5}	1.540×10^{-3}	1.545×10^{-7}	0.01381	
400	9908	148.2	16.10	1.096×10^{-5}	1.422×10^{-3}	1.436×10^{-7}	0.01310	
500	9785	152.8	15.74	1.052×10^{-5}	1.188×10^{-3}	1.215×10^{-7}	0.01154	
600	9663	157.3	15.60	1.026×10^{-5}	1.013×10^{-3}	1.048×10^{-7}	0.01022	
700	9540	161.8	15.60	1.010×10^{-5}	8.736×10^{-4}	9.157×10^{-8}	0.00906	
				Lead (Pb) Melting Point: 327°C				
400	10506	158	15.97	9.623×10^{-6}	2.277×10^{-3}	2.167×10^{-7}	0.02252	
450	10449	156	15.74	9.649×10^{-6}	2.065×10^{-3}	1.976×10^{-7}	0.02048	
500	10390	155	15.54	9.651×10^{-6}	1.884×10^{-3}	1.814×10^{-7}	0.01879	
550	10329	155	15.39	9.610×10^{-6}	1.758×10^{-3}	1.702×10^{-7}	0.01771	
600	10267	155	15.23	9.568×10^{-6}	1.632×10^{-3}	1.589×10^{-7}	0.01661	
650	10206	155	15.07	9.526×10^{-6}	1.505×10^{-3}	1.475×10^{-7}	0.01549	
700	10145	155	14.91	9.483×10^{-6}	1.379×10^{-3}	1.360×10^{-7}	0.01434	
				Sodium (Na) Melting Point: 98°C				
100	927.3	1378	85.84	6.718×10^{-5}	6.892×10^{-4}	7.432×10^{-7}	0.01106	
200	902.5	1349	80.84	6.639×10^{-5}	5.385×10^{-4}	5.967×10^{-7}	0.008987	
300	877.8	1320	75.84	6.544×10^{-5}	3.878×10^{-4}	4.418×10^{-7}	0.006751	
400	853.0	1296	71.20	6.437×10^{-5}	2.720×10^{-4}	3.188×10^{-7}	0.004953	
500	828.5	1284	67.41	6.335×10^{-5}	2.411×10^{-4}	2.909×10^{-7}	0.004593	
600	804.0	1272	63.63	6.220×10^{-5}	2.101×10^{-4}	2.614×10^{-7}	0.004202	
				Potassium (K) Melting Point: 64°C				
200	795.2	790.8	43.99	6.995×10^{-5}	3.350×10^{-4}	4.213×10^{-7}	0.006023	
300	771.6	772.8	42.01	7.045×10^{-5}	2.667×10^{-4}	3.456×10^{-7}	0.004906	
400	748.0	754.8	40.03	7.090×10^{-5}	1.984×10^{-4}	2.652×10^{-7}	0.00374	
500	723.9	750.0	37.81	6.964×10^{-5}	1.668×10^{-4}	2.304×10^{-7}	0.003309	
600	699.6	750.0	35.50	6.765×10^{-5}	1.487×10^{-4}	2.126×10^{-7}	0.003143	
				Sodium-Potassium (%22Na-%78K) Melting Point: −11°C				
100	847.3	944.4	25.64	3.205×10^{-5}	5.707×10^{-4}	6.736×10^{-7}	0.02102	
200	823.2	922.5	26.27	3.459×10^{-5}	4.587×10^{-4}	5.572×10^{-7}	0.01611	
300	799.1	900.6	26.89	3.736×10^{-5}	3.467×10^{-4}	4.339×10^{-7}	0.01161	
400	775.0	879.0	27.50	4.037×10^{-5}	2.357×10^{-4}	3.041×10^{-7}	0.00753	
500	751.5	880.1	27.89	4.217×10^{-5}	2.108×10^{-4}	2.805×10^{-7}	0.00665	
600	728.0	881.2	28.28	4.408×10^{-5}	1.859×10^{-4}	2.553×10^{-7}	0.00579	

Source: Data generated from the EES software developed by S. A. Klein and F. L. Alvarado. Originally based on various sources.

TABLE 11–2

Blackbody radiation functions f_λ

λT, $\mu m \cdot K$	f_λ	λT, $\mu m \cdot K$	f_λ
200	0.000000	6200	0.754140
400	0.000000	6400	0.769234
600	0.000000	6600	0.783199
800	0.000016	6800	0.796129
1000	0.000321	7000	0.808109
1200	0.002134	7200	0.819217
1400	0.007790	7400	0.829527
1600	0.019718	7600	0.839102
1800	0.039341	7800	0.848005
2000	0.066728	8000	0.856288
2200	0.100888	8500	0.874608
2400	0.140256	9000	0.890029
2600	0.183120	9500	0.903085
2800	0.227897	10,000	0.914199
3000	0.273232	10,500	0.923710
3200	0.318102	11,000	0.931890
3400	0.361735	11,500	0.939959
3600	0.403607	12,000	0.945098
3800	0.443382	13,000	0.955139
4000	0.480877	14,000	0.962898
4200	0.516014	15,000	0.969981
4400	0.548796	16,000	0.973814
4600	0.579280	18,000	0.980860
4800	0.607559	20,000	0.985602
5000	0.633747	25,000	0.992215
5200	0.658970	30,000	0.995340
5400	0.680360	40,000	0.997967
5600	0.701046	50,000	0.998953
5800	0.720158	75,000	0.999713
6000	0.737818	100,000	0.999905

TABLE 13–3

Nusselt number for fully developed laminar flow in a circular annulus with one surface insulated and the other isothermal (Kays and Perkins, Ref. 8.)

D_i/D_o	Nu_i	Nu_o
0.00	—	3.66
0.05	17.46	4.06
0.10	11.56	4.11
0.25	7.37	4.23
0.50	5.74	4.43
1.00	4.86	4.86