ตารางแนบท้าย

TABLE 1. The Seven SI Base Units

Quantity	Name of unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	sec
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Luminous intensity	Candela	cd
Amount of a substance	Mole	mol

TABLE 2. SI Derived Units

Quantity	Name of unit	Symbol
Acceleration	Meters per second squared	m/sec^2
Area	Square meters	m^2
Density	Kilogram per cubic meter	kg/m^3
Dynamic viscosity	Newton-second per square meter	$N \cdot sec/m^2$
Force	Newton (= 1 $kg \cdot m/sec^2$)	N
Frequency	Hertz	HZ
Kinematic viscosity	Square meter per second	m^2/sec
Plane angle	Radian	rad
Potential difference	Volt	V
Power	Watt (= 1 J/s)	W
Pressure	Pascal (= 1 N/m^2)	Pa
Radiant intensity	Watts per steradian	W/sr
Solid angle	Steradian	sr
Specific heat	Joules per kilogram-Kelvin	$J/kg \cdot K$
Thermal conductivity	Watts per meter-Kelvin	$W/m \cdot K$
Velocity	Meters per second	m/sec
Volume	Cubic meter	m^3
Work, energy, heat	Joule (= 1 N m)	J

TABLE 3. SI Prefixes

Multiplier	Symbol	Prefix
10^{12}	T	Tera
10^{9}	G	Giga
10^{6}	M	Mega
10^{3}	k	Kilo
10^{2}	h	Hecto
10^{1}	da	Deka
10^{-1}	d	Deci
10^{-2}	c	Centi
10^{-3}	m	Milli
10^{-6}	μ	Micro
10^{-9}	n	Nano
10^{-12}	p	Pico
10^{-15}	f	Femto
10^{-18}	a	Atto

TABLE 4. Physical Constants in SI Units

Quantity	Symbol	Value
Avogadro constant	N	6.022169×10^{26} kmol^{-1}
Boltzmann constant	k	1.380622×10^{-23} J/K
First radiation constant	$C_1 = 2\pi hc^2$	3.741844×10^{-16} W · m^2
Gas constant	R	8.31434×10^{3} J/kmol · K
Planck constant	h	6.626198×10^{-34} J · sec
Second radiation constant	$C_2 = hc/k$	1.438833×10^{-2} m · K
Speed of light in a vacuum	c	2.997925×10^{8} m/sec
Stefan-Boltzmann constant	σ	5.66961×10^{-8} W/m^2 · K^4

TABLE 5. Conversion Factors

Physical quantity	Symbol	Conversion factor
Area	A	1 ft^2 = 0.0929 m^2
		1 in^2 = 6.452×10^{-4} m^2
Density	ρ	1 lb_m/ft^3 = 16.018 kg/m^3
		1 slug/ft^3 = 515.379 kg/m^3
Heat, energy, or work	Q or W	1 Btu = 1055.1 J
		1 cal = 4.186 J
		1 ft · lb_f = 1.3558 J
		1 hp · hr = 2.685×10^{6} J
Force	F	1 lbf = 4.448 N
Heat flow rate	q	1 Btu/hr = 0.2931 W
		1 Btu/sec = 1055.1 W
Heat flux	q/A	1 Btu/hr · ft^2 = 3.1515 W/m^2
Heat-transfer coefficient	h	1 Btu/hr · ft^2 · °F = 5.678 W/m^2 · K
Length	L	1 ft = 0.3048 m
		1 in = 2.54 cm
		1 mi = 1.6093 km
Mass	m	1 lb_m = 0.4536 kg
		1 slug = 14.594 kg
Mass flow rate	$\dot{m}$	1 lb_m/hr = 0.000126 kg/s
		1 lb_m/sec = 0.4536 kg/sec
Power	$\dot{W}$	1 hp = 745.7 W
		1 ft · lb_f/sec = 1.3558 W
		1 Btu/sec = 1055.1 W
		1 Btu/hr = 0.293 W
Pressure	p	1 lb_f/in^2 = 6894.8 Pa (N/m^2)
		1 lb_f/ft^2 = 47.88 Pa (N/m^2)
		1 atm = 101,325 Pa (N/m^2)
Radiation	I	1 langley = 41,860 J/m^2
Specific heat capacity	c	1 Btu/lb_m · °F = 4187 J/kg · K
Internal energy or enthalpy	e or h	1 Btu/lb_m = 2326.0 J/kg
		1 cal/g = 4184 J/kg
Temperature	T	$T(°R) = (9/5)T(K)$
		$T(°F) = [T(°C)](9/5) + 32$
		$T(°F) = [T(K) - 273.15](9/5) + 32$

Thermal conductivity	k	1 Btu/hr · ft · °F = 1.731 W/m K
Thermal resistance	R_{th}	1 hr · °F/Btu = 1.8958 K/W
Velocity	V	1 ft/sec = 0.3048 m/sec
		1 mi/hr = 0.44703 m/sec
Viscosity, dynamic	μ	1 lb_m/ft · sec = 1.488 N · sec/m²
		1 cP 0.00100 N sec/m²
Viscosity, kinematic	ν	1 ft²/sec = 0.09029 m²/sec
		1 ft²/hr = 2.581×10^{-5} m²/sec
Volume	V	1 ft³ = 0.02832 m³
		1 in³ = 1.6387×10^{-5} m³
		1 gal (U.S. liq.) = 0.003785 m³
Volumetric flow rate	$\dot{Q}$	1 ft³/min = 0.000472 m³/sec

TABLE 6. Properties of Dry Air at Atmospheric Pressures between 250 and 1000 K[a]

T^b (K)	ρ (kg/m³)	c_p (kJ/kg · K)	μ (kg/m sec $\times 10^5$)	ν (m²/sec $\times 10^6$)	k (W/m · K)	α (m²/sec $\times 10^4$)	Pr
250	1.4128	1.0053	1.488	9.49	0.02227	0.13161	0.722
300	1.1774	1.0057	1.983	15.68	0.02624	0.22160	0.708
350	0.9980	1.0090	2.075	23.76	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	28.86	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	3190	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	0.681
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	3.686
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

[a]From *Natl. Bureau Standards (U.S.) Circ.* 564, 1955.

[b]Symbols: K = absolute temperature, degrees Kelvin; $\nu = \mu/\rho$; ρ = density; c_p = specific heat capacity; $\alpha = c_p\rho/k$; μ = viscosity; k = thermal conductivity; Pr = Prandtl number, dimensionless. 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.

TABLE 7. Properties of Water (Saturated Liquid) between 273 and533 K[a]

T			c_p	ρ	μ	k		$\frac{g\beta\rho^2 c_p}{\mu k}$
K	°F	°C	(kJ/kg · °C)	(kg/m³)	(kg/m · sec)	(W/m · °C)	Pr	(m⁻³ · °C⁻¹)
273	32	0	4.225	999.8	1.79×10^{-3}	0.566	13.25	
277.4	40	4.44	4.208	999.8	1.55	0.575	11.35	1.91×10^{9}
283	50	10	4.195	999.2	1.31	0.585	9.40	6.34 X 10'
288.6	60	15.56	4.186	998.6	1.12	0.595	7.88	1.08×10^{10}
294.1	70	21.11	4.179	997.4	9.8×10^{-4}	0.604	6.78	1.46×10^{10}
299.7	80	26.67	4.179	395.8	8.6	0.614	5.85	1.91×10^{10}
302.2	90	32.22	4.174	994.9	7.65	0.623	5.12	2.48×10^{10}
310.8	100	37.78	4.174	993.0	6.82	0.630	4.53	3.3×10^{10}
316.3	110	43.33	4.174	790.6	6.16	0.637	4.04	4.19×10^{10}
322.9	120	48.89	4.174	988.8	5.62	0.644	3.64	4.89×10^{10}
327.4	130	54.44	4.179	985.7	5.13	0.649	3.30	5.66×10^{10}
333.0	140	60	4.179	983.3	4.71	0.654	3.01	6.48×10^{10}
338.6	150	65.55	4.183	980.3	4.3	0.659	2.73	7.62×10^{10}
342.1	160	71.11	4.186	977.3	4.01	0.665	2.53	8.84×10^{10}
349.7	170	76.67	4.191	973.7	3.72	0.668	2.33	9.85×10^{10}
355.2	180	82.22	4.195	970.2	3.47	0.673	2.16	1.09×10^{11}
360.8	190	87.78	4.199	966.7	3.27	0.675	2.03	
366.3	200	93.33	4.204	963.2	3.06	0.678	1.90	
317.4	220	104.4	4.216	355.1	2.67	0.684	1.66	
382.6	240	115.6	4.229	946.7	2.44	0.6115	1.51	
399.1	260	126.7	4.250	937.2	2.19	0.685	1.36	
410.8	280	137.8	4.271	928.1	1.98	0.685	1.24	
421.9	300	148.9	4.296	318.0	1.86	0.684	1.17	
449.1	350	176.7	4.371	890.4	1.57	0.677	1.02	
477.4	400	204.4	4.467	853.4	1.36	0.665	1.00	
505.2	450	232.2	4.585	825.7	1.20	0.646	0.85	
533.0	500	260	4.731	785.2	1.07	0.616	0.83	

*Adapted from Brown, A. I., and S. M Marco, "Introduction to Heat Transfer." 3d ed., McGraw-Hill Book Company, New York, 1958.

TABLE 8. Emittances and Absorptances of Materials

Substance	Short-wave absorptance	Long-wave emittance	$\frac{\alpha}{\epsilon}$
Class substances: Absorptance to emittance ratios less than 0.5			
Magnesium carbonate, $MgCO_3$	0.025-0.04	0.79	0.03-0.05
White plaster	0.07	0.91	0.08
Snow, fine particles, fresh	0.13	0.82	0.16
White paint, 0.017 in, on aluminum	0.20	0.91	0.22
Whitewash on galvanized iron	0.22	0.90	0.24
White paper	0.25-0.28	0.95	0.26-0.29
White enamel on iron	0.25-0.45	0.9	0.28-0.5
Ice, with sparse snow cover	0.31	0.96-0.97	0.32
Snow, icegranules	0.33	0.89	0.37
Aluminum oil base paint	0.45	0.90	0.50
White powdered sand	0.45	0.84	0.54

TABLE 8. Emittances and Absorptances of Materials[a] (*Continued*)

substance	Short-wave absorptance	Long-wave emittance	$\frac{\alpha}{\epsilon}$
Class II substances: Absorptance to emittance ratios between 0.5 and 0.9			
Asbestos felt	0.25	0.50	0.50
Green oil base paint	0.5	0.9	0.56
Bricks, red	0.55	0.92	0.60
Asbestos cement board, white	0.59	0.96	0.61
Marble, polished	O.S-0.6	0.9	0.61
Wood, planed oak		0.9	
Rough concrete	0.60	0.97	0.62
Concrete	0.60	0.88	0.68
Grass, green, after rain	0.67	0.98	0.68
Grass, high and dry	0.67-0.69	0.9	0.76
Vegetable fields and shrubs, wilted	0.70	0.5	0.78
Oak leaves	0.71-0.78	0.91-0.9s	0.78-0.82
Frozen soil		0.93-0.94	
Desert surface	0.75	0.9	0.83
Common vegetable fields and shrubs	0.72-0.76	0.9	0.82
Ground, dry plowed	0.75 -0.80	0.	0.83-0.89
Oak woodland	0.82	0	0.91
Pine forest	0.86	0."	0.96
Earth surface as a whole (land and sea, no clouds)	0.83		
Class III substances: Absorptance to emittance ratios between 0.8 and 1.0			
Grey paint	0.75	0.95	0.79
Red oil base paint	0.74	0.90	0.82
Asbestos, slate	0.81	0.96	0.84
Asbestos. paper		0.93-0.96	
Linoleum, red-brown	0.84	0.92	0.91
Dry sand	0.82	0.90	0.91
Green roll roofing	0.88	0.91-0.97	0.93
Slate, dark grey	0.89		
Old grey rubber		0.86	
Hard black rubber		0.90-0.9s	
Asphalt pavement	0.93		
Black cupric oxide on copper	0.91	0.96	0.95
Bare moist ground	0.9	0.95	0.95
Wet sand	0.91	0.95	0.96
Water	0.94	0.95-0.96	0.98
Black tar paper	0.93	0.93	1.0
Black gloss paint	0.90	0.90	1.0
Small hole in large box, furnace, or enclosure	0.99	0.99	1.0
"Hohlraum," theoretically perfect black body	1.0	1.0	1.0

'TABLE 8. Emittances and Absorptances of Materials[a] (Continued)

Substance	Short-wave absorptance	Long-wave emittance	$\frac{\alpha}{\epsilon}$
Class IV substances: Absorptance to emittance ratios greater than 1.0			
Black silk velvet	0.99	0.97	1.02
Alfalfa, dark green	0.97	0.95	1.02
Lampblack	0.98	0.95	1.03
Black paint, 0.017 in, on aluminum	0.94-0.98	0.88	1.07-1.11
Granite	0.55	0.44	1.25
Graphite	0.78	0.41	1.90
High ratios. but absorptances less than 0.80			
Dull brass, copper, lead	0.2-0.4	0.4-0.65	1.63-2.0
Galvanized sheet iron, oxidized	0.8	0.28	2.86
Galvanized iron, clean. new	0.65	0.13	5.0
Aluminum foil	0.15	0.05	3.00
Magnesium	0.3	0.07	4.3
Chromium	0.49	0.08	6.13
Polished zinc	0.46	0.02	23.0
Deposited silver (optical reflector) untarnished	0.07	0.01	
Class V substances: Selective surfaces[b]			
Plated metals:[c]			
Black sulfide on metal	3.92	II.10	9.2
Black cupric oxide on sheet aluminum	0.08-0.93	0.09-0.21	
Copper (5×10^{-5} cm thick) on nickel or silver-plated metal			
Cobalt oxide on platinum			
Cobalt oxide on polished nickel	0.93-0.94	0.24-0.40	3.9
Black nickel oxide on aluminum	0.85-0.93	0.06-0.1	14.5-15.5
Black chrome	0.87	0.09	9.8
Particulate coatings:			
Lampblack on metal			
Black iron oxide, 47 μm grain size. on aluminum			
Geometrically enhanced surfaces!			
Optimally corrugated greys	0.89	0.77	1.2
Optimally corrugated selectives	0.95	0.16	5.9
Stainless-steel wire mesh	0.63-0.86	0.23-0.28	2.7-3.0
Copper, treated with $NaClO_2$ and NaOH	0.81	0.13	6.69

'From Anderson, B., "Solar Energy," McGraw-Hill Book Company, 1977, with permission,

[b]Selective surfacer absorb most of the solar radiation between 0.3 and 1.9 μm, and emit very little in the 5-15 μm range-the infrared.

'For a discussion of plated selective surfaces, see Daniels, "Direct Use of the Sun's Energy " especially chapter 12.

[d]For a discussion of how surface selectivity can be enhanced through surface geometry, see K. G. T. Hollands, Directional Selectivity Emittance and Absorptance Properties of Vee Corrugated Specular Surfaces, *J. Sol. Energy Sci. Eng.*, vol. 3, July 1963.

TABLE 9. Thermal Properties of Some Nonmetals[a]

Material	Average temperature, °F	k, Btu/(hr)(ft)(°F)	c, Btu/(lb_m)(°F)	ρ, lb_m/ft^3	α, ft^2/hr
Insulating materials					
Asbestos	32	0.087	0.25	36	-0.01
	392	0.12		36	-0.01
Cork	86	0.025	0.04	10	~0.006
Cotton, fabric	200	0.046			
Diatomaceous earth, powdered	100	0.030	0.21	14	-0.0,
	300	0.036			
	600	0.046			
Molded pipe covering	400	0.051		lb	
	1600	0.088			
Glass wool					
Fine	20	0.022			
	100	[illegible]		1.5	
	200	0.043			
Packed	20	0.016			
	100	0.022		6.0	
	200	0.029			
Hair felt	100	0.027		8.2	
Kaolin insulating brick	932	0.15		27	
	2102	0.26			
Kaolin insulating firebrick	392	0.05		19	
	1400	0.1 I			
85% magnesia	32	0.032		17	
	200	0.037		17	
Rock wool	20	0.017		8	
	200	0.030			
Rubber	32	0.087	0.48	75	0.0024
Building materials					
Brick					
Fire-clay	392	0.58	0.20	144	0.02
	1832	0.95			
Masonry	70	0.38	0.20	106	0.018
Zirconia	392	0.84		304	
	,832	1.13			
Chrome brick	392	0.82		246	
	1832	0.96			
Concrete					
Stone	-70	0.54	0.20	144	0.019
10% Moisture	~70	0.70		140	0.025
Glass, window	-70	-0.45	0.2	170	0.013
Limestone, dry	70	0.40	0.22	105	0.017
Sand					
Dry	68	0.20		95	
10% H_2O	68	0.60		100	
Soil					
Dry	70	-0.20	0.44		0.01
Wet	70	-1.5	. .		0.03
Wood					
Oak ⊥ to grain	70	0.12	0.57	5,	0.004,
∥ to grain	70	0.20	0.57	51	0.0069
Pine ⊥ to grain	70	0.06	0.67	3,	0.0029
∥ to grain	70	0.14	0.67	3,	0.0067
Ice	32	1.28	0.46	57	0.048

[a]From Kreith, F.. "Principles of Heat Transfer," Intext Educational Publishers., New York. 1973.

TABLE 10. **Thermal** Properties of **Metals** and **Alloys**[a]

Material	k, Btu/(hr)(ft)(°F)				c, Btu/(lb$_m$)(°F)	ρ, lb$_m$/ft^3	α ft^2/hr
	32°F	212°F	572°F	932°F	32°F	32°F	32°F
Metals							
Aluminum	117	119	133	155	0.208	169	3.33
Bismuth	4.9	3.9	...	...	0.029	612	0.28
Copper, pure	224	218	212	207	0.091	558	4.42
Gold	169	170	...	...	0.030	1203	4.68
Iron, pure	35.8	36.6	...	...	0.104	491	0.70
Lead		19	18		0.030	705	0.95
Magnesium	91	92	...	...	0.232	109	3.60
Mercury	4.8		...	...	0.033	849	0.17
Nickel	34.5	34	32	...	0.103	555	0.60
Silver	242	238	...	...	0.056	655	6.6
Tin	36	34	...	...	0.054	456	1.46
Zinc	65	64	59	...	0.091	446	1.60
Alloys							
Admiralty metal	65	64					
Brass, 70% Cu, 30% Zn	56	60	66	...	0.092	532	1.14
Bronze, 75% Cu, 25% Sn	15		...	...	0.082	540	0.34
Cast iron							
Plain	33	31.8	27.7	24.8	0.11	474	0.63
Alloy	30	28.3	27	...	0.10	455	0.66
Constantan, 60% Cu, 40% Ni	12.4	12.8	...	...	0.10	557	0.22
18-8 Stainless steel							
Type 304	8.0	9.4	10.9	12.4	0.11	488	0.15
Type 347	8.0	9.3	11.0	12.8	0.11	488	0.15
Steel, mild, 1% C	26.5	26	25	22	0.11	490	0.49

[a]From Kreith, F., "Principles of Hear Transfer," Intel: Educational Publishers, New York, 1973