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ERRATA

THERMAL RADIATION HEAT TRANSFER

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Page	Correction
11	Eq. (1.6): the RHS should be 2π, not 4π.
27	Fig. 1.16: In the caption, replace "crosshatched" with "light gray".
	Second line in first paragraph, replace "crosshatched" with "light gray".
28	Fig. 1.17: On the x-axis, replace 10^0 with 10^3, and 10^1 with 10^4.
55	In Figure 2.2e, on the incoming ray, replace $I_i(\theta_r,\phi_i,T_s)$ with $I_i(\theta_i,\phi_i,T_s)$.
	In Figure 2.2e, on the reflected ray, replace $I_r(\theta,\phi,\theta_r,\phi_i,T_s)$ with $I_r(\theta_r,\phi_r,\theta_i,\phi_i,T_s)$.
	In Figure 2.2e, for the reflected ray, the angles with respect to the axes should be θ_r and ϕ_r, not θ and ϕ.
	Revise the caption to Figure 2.2 to read:
	"Pictorial descriptions …………, the subscript λ is added to the property definitions: (a) ………; (e) bi-directional reflectivity $\rho\left(\theta_r,\phi_r,\theta_i,\phi_i,T\right)$; (f)………"
56	In Figure 2.2i, for the incoming ray, replace the azimuthal angle θ_r with θ_i.
	In Figure 2.2i, for the transmitted ray, replace $I_t(\theta_r,\phi_i,\theta_t,\phi_t,T_s)$ with $I_t(\theta_i,\phi_i,\theta_t,\phi_t,T_s)$.
	In the caption **Figure 2.2 (Continued)**, second line, revise to read "….. the subscript λ is added to the property………"
63	In the line after Eq. (2.11), replace $dA\cos\theta / R^2$ with $dA\cos\theta_i / R^2$
	At end of line after Eq. (2.11), add "….. as in Figure 2.7a."
163	In Eq. (4.15) the RHS should read dA_1F_{d1-2}
186	Some limits on the integrals in both equations are incorrect. The correct equations should be:

$$F_{1-2} = \frac{1}{2\pi ab}\oint_{C_1}\left\{\int_{y_2=0}^{b} \ln\left[x_1^2 + (y_2-y_1)^2 + c^2\right]^{1/2} dy_2 \right.$$

$$\left. + \int_{y_2=b}^{0} \ln\left[(a-x_1)^2 + (y_2-y_1)^2 + c^2\right]^{1/2} dy_2 \right\} dy_1$$

$$+ \frac{1}{2\pi ab}\oint_{C_1}\left\{\int_{x_2=0}^{a} \ln\left[(x_2-x_1)^2 + (b-y_1)^2 + c^2\right]^{1/2} dx_2 \right.$$

$$\left. + \int_{x_2=a}^{0} \ln\left[(x_2-x_1)^2 + y_1^2 + c^2\right]^{1/2} dx_2 \right\} dx_1$$

and

$$2\pi ab F_{1-2} = \int_{y_1=0}^{b}\int_{y_2=0}^{b} \ln\left[a^2 + (y_2-y_1)^2 + c^2\right]^{1/2} dy_2 dy_1$$

$$+ \int_{y_1=b}^{0}\int_{y_2=0}^{b} \ln\left[(y_2-y_1)^2 + c^2\right]^{1/2} dy_2 dy_1$$

$$+ \int_{y_1=0}^{b}\int_{y_2=0}^{0} \ln\left[(y_2-y_1)^2 + c^2\right]^{1/2} dy_2 dy_1$$

$$+ \int_{y_1=b}^{0}\int_{y_2=b}^{0} \ln\left[a^2 + (y_2-y_1)^2 + c^2\right]^{1/2} dy_2 dy_1$$

$$+ (4 \text{ integral terms in } x)$$

$$= \int_{y_1=0}^{b}\int_{y_2=0}^{b} \ln\left[\frac{a^2 + (y_2-y_1)^2 + c^2}{(y_2-y_1) + c^2}\right] dy_2 dy_1$$

$$+ \int_{x_1=0}^{a}\int_{x_2=0}^{a} \ln\left[\frac{(x_2-x_1)^2 + b^2 + c^2}{(x_2-x_1)^2 + c^2}\right] dx_2 dx_1$$

187 Fig. 4.24a: The element dA_2 is meant to be a strip element that goes completely around the interior of the square channel.

222 In text line above Eq. (5.9.1), ε_2 should be plain text, not bold.

239 In Eq. (5.49), on the LHS, replace J_k with G_k.

242 The upper limit in Eq. (5.19.1) should be $\eta = l$, not $\eta = 1$.

273 Section 6.2, first paragraph, at end of line modify to read " ….from directional ones, and one can understand…"

293 Fig. 6.15(d): For path *b*, the uppermost arrowhead should be reversed.

294 Example 6.8, second paragraph, first line, should read "The cooling rate of the coffee is $\rho_M Vc\frac{dT_1}{dt}$. Assuming….."

355 Example 7.7, first paragraph, next to last line, replace "…heat capacity c_P…" with "…

specific heat c_P…".

396 In Fig. 7.30, replace j = N with j = J.

396-7 Replace all text beginning after first paragraph in "*Black surface enclosures*" and ending above Section 7.9.6 with:

Now, N sample bundle reverse paths are originated from dA_k, and their point of intersection with the enclosure surface at location $\mathbf{r}_j$ is found. Each individual bundle n_{j-k} is then assigned energy $w_j = \frac{\left[\sigma T_j^4(\mathbf{r}_j)\right]}{N}$. The value of irradiation on the element dA_k is then

$$G(\mathbf{r}_k) = \sum_{j=1}^{J} n_{j-k} w_j = \frac{\sigma}{N} \sum_{j=1}^{J} n_{j-k} T_j^4(\mathbf{r}_j) \tag{7.63}$$

and the local flux $q_k(\mathbf{r}_k)$ is easily found from Equation 7.62.

Diffuse surface enclosures: Now, consider an enclosure with nongray but diffuse surfaces. The spectral radiative flux at any wavelength is found from

$$\begin{aligned} q_{k,\lambda}(\mathbf{r}_k) &= J_{k,\lambda}(\mathbf{r}_k) - G_{k,\lambda}(\mathbf{r}_k) \\ &= \left[\varepsilon_{k,\lambda} E_{\lambda b}(\mathbf{r}_k) + (1-\varepsilon_{k,\lambda}) G_{k,\lambda}(\mathbf{r}_k)\right] - G_{k,\lambda}(\mathbf{r}_k) = \varepsilon_{k,\lambda}\left[E_{\lambda b}(\mathbf{r}_k) - G_{k,\lambda}(\mathbf{r}_k)\right] \end{aligned} \tag{7.64}$$

and the total flux is

$$q_k(\mathbf{r}_k) = \int_{\lambda=0}^{\infty} \varepsilon_{k,\lambda}\left[E_{\lambda b}(\mathbf{r}_k) - G_{k,\lambda}(\mathbf{r}_k)\right] d\lambda = \varepsilon_k \sigma T_k^4(\mathbf{r}_k) - \int_{\lambda=0}^{\infty} \varepsilon_{k,\lambda} G_{k,\lambda}(\mathbf{r}_k) d\lambda \tag{7.65}$$

Finding the total absorbed radiative flux on nongray–diffuse surface dA_k then reduces to finding the value of the final integral in Equation 7.65. In reverse Monte Carlo, this is done by again determining the weighted energy of the absorbed incident bundles, assigned by following the reverse bundle paths. Now, however, the energy carried by the bundle is complicated by the interreflections among the diffuse surfaces along the bundle reverse history (Figure 7.31); that is, the radiosity of each surface j must be taken into account.

The reverse path is followed by initiating the reverse path for N absorbed bundles on surface k as for the black case, except that a wavelength must also be assigned to the bundle through Equation 7.52, or for the nongray–diffuse surface k:

$$R_\lambda = \frac{\int_{\lambda^*=0}^{\lambda} \varepsilon_\lambda E_{\lambda b}(\mathbf{r}_k) d\lambda^*}{\varepsilon_k \sigma T_k^4(\mathbf{r}_k)} \tag{7.66}$$

Equation 7.66 can be curve fit as for Equation 7.53. Upon intersection of the bundle with an enclosure surface j, a decision is made as to whether the bundle originated at that surface by emission or was reflected from that surface. This is done by next determining the spectral absorptivity of the intersected surface at the wavelength determined from Equation 7.66, $\alpha_{j,\lambda} = \varepsilon_{j,\lambda}$. A new random number R is chosen, and if $R \le \alpha_{j,\lambda}$, the bundle is assumed to have been emitted by the intersected surface and is assigned the energy $w_{j,\lambda} = \varepsilon_{j,\lambda} E_{\lambda b,j}(\mathrm{r}_j)/N$, and its reverse history is terminated. If, however, $R > \alpha_{j,\lambda}$, the bundle is assumed to have been reflected from the intersected surface, and its history is continued by choosing a further inverse reflected path by choosing the diffuse angles (θ_i, ϕ_i) using the diffuse relations of Equation 7.58 and 7.59. This process is continued through multiple reflections until the location of origin surface j is found. Many reverse bundle paths N are then followed from surface k, and the number of these samples diagnosed as leaving surface *j* and incident on *k*, $n_{j-k,}$ is tallied along with their energy, $w_{j,\lambda}$. Note that detailed balancing requires $n_{j-k}\varepsilon_j = n_{k-j}\varepsilon_k$,

The integral term in Equation 7.65 is then given by

$$\begin{aligned}\int_{\lambda=0}^{\infty}\alpha_{k,\lambda}G_{k,\lambda}\left(\mathrm{r}_k\right)d\lambda &= \sum_{j=1}^{J} n_{j-k}\int_{\lambda=0}^{\infty} w_{j,\lambda}d\lambda = \sum_{j=1}^{J}\frac{n_{j-k}}{N}\int_{\lambda=0}^{\infty}\varepsilon_{j,\lambda}E_{\lambda b,j}\left(\mathrm{r}_j\right)d\lambda \\ &= \sum_{j=1}^{J}\frac{n_{j-k}}{N}\varepsilon_j\sigma T_j^4\left(\mathrm{r}_j\right) = \varepsilon_k\sum_{j=1}^{J}\frac{n_{k-j}}{N}\sigma T_j^4\left(\mathrm{r}_j\right)\end{aligned} \tag{7.67}$$

which can be tallied "on the fly" without intermediate storage of w_j for each bundle.

If the enclosure surfaces are not diffuse, then the reciprocity relations shown for reflectivity can be invoked to allow following reverse paths that account for directional surface properties.

If all surfaces are both gray and diffuse, then substituting Equation 7.67 into Equation 7.65 gives

$$q_k\left(\mathbf{r}_k\right) = \varepsilon_k\sigma T_k^4\left(\mathbf{r}_k\right) - \frac{1}{N}\sum_{j=1}^{J}\alpha_k n_{k-j}\sigma T_j^4\left(\mathbf{r}_j\right) \overset{\alpha_k=\varepsilon_k}{\rightarrow} \varepsilon_k\sigma\sum_{j=1}^{J}\left[T_k^4\left(\mathbf{r}_k\right) - \frac{n_{k-j}}{N}T_j^4\left(\mathbf{r}_j\right)\right] \tag{7.68}$$

Observe that the forward Monte Carlo approach uses equal-energy bundles and follows their paths from origin to point of absorption and gives the correct angular distribution of irradiation onto the absorbing surface. In contrast, the reverse Monte Carlo procedure assumes a uniform distribution of *number* of bundles *N* in the irradiation but determines the correct angular distribution of irradiation through correctly weighting the energy per incident bundle.

397	In Fig. 7.31, replace j = N with j = J.
544	In Eq. (11.26), insert a + between the last two integrals.
769	Line above Eq. (15.37). For nonabsorbing medium, should be: (k_1 = 0).
773	Eq. (15.54): the a_j and b_j should not be squared.
774	Eq. (15.58): a multiplier of 4π should replace the 1 in the numerator on the RHS.
916	The reference to Chan, S. and Ge, X.S. should be to Chen, S. and Ge, X.S., and should be reordered alphabetically.