ME 353 M.M. Yovanovich

Week 12

Lecture 1

Project 2 will be returned tomorrow.
Radiation: Chapters 12 and 13; see Web site for lecture material and some Maple worksheets for view factors.
Black body radiation from isothermal surfaces, e.g. a small conical cavity in a large isothermal body; all radiation "falling" on the opening vanishes inside the cavity; radiation emitted by the cavity appears to come from a black-body source.
Planck's distribution law relates the emissive power to the radiaion wavelength and the temperature of the isothermal source; Wien's displacement law relates the wavelength at which the emissive power is a maximum for a fixed absolute temperature: $\lambda_{\max}T = 2897.8\,[\mu m K]$; Stefan-Boltzmann law of radiation for an isothermal black-body: $E_b = \int_0^\infty E_{b,\lambda}\,d\lambda = \sigma T^4\ [W/m^2]$; Stefan-Boltzmann constant: $\sigma = 5.67 \times 10^{-8}\ [W/m^2K^4]$; real surface radiation is less than a black-body at the same absolute temperature: $E = \epsilon E_b = \epsilon\sigma T^4$; ϵ is the total hemispherical emittance (emissivity) where $0 < \epsilon < 1$; it is a function of the material, condition of the surface, temperature of the surface, etc.; ϵ is determined by experiment; radiation incident on the surface of a layer of some substance (gas, liquid or solid) can in general be transmitted through the layer, aborbed in the layer, or reflected from the surface of the layer; give general relation between: absorptivity, α, reflectivity, ρ, and transmissivity, τ: $\alpha + \rho + \tau = 1$;
for most solids: $\tau = 0$ and $\alpha + \rho = 1$; for most light gases: $\tau = 1$ and $\rho = 0$ and $\alpha = 1$; exceptions are carbon dioxide and water vapor which absorb radiation in certain wavelengths; specular and diffuse surface reflection: specular reflection occurs when surface is smooth, highly polished, clean; optical laws apply; diffuse reflection occurs when the surface is rough, oxidized, dirty, etc.

Lecture 2

Kirchhoff's law relates the emissivity and the absorptivity: $\epsilon = \alpha$; gray surface; radiation between two isothermal, convex surfaces; radiation view factors: F_{12}, F_{21}; reciprocity relation: $A_1F_{12} = A_2F_{21}$; relations: $F_{11} + F_{12} = 1$

and $F_{21} + F_{22} = 1$; for convex surfaces: $F_{11} = F_{22} = 0$; for concave surfaces: $0 < F_{11} < 1$ and $0 < F_{22} < 1$; discuss procedure to find relations for view factors for the fundamental problem which is a two-dimensional system which consists of three convex, isothermal gray surfaces: A_1, A_2, A_3; discuss Hottel *crossed-string method* for two-dimensional, two surface systems; examples of view factors; see Maple worksheets on the Web and Tables 13.1 and 13.2; black-body radiation exchange; spatial radiation resistance: $\mathcal{R}_{12} = 1/(A_1 F_{12}) = 1/(A_2 F_{21})$; equivalent radiation circuit; net radiative exchange between two isothermal, gray surfaces: (A_1, ϵ_1, T_1) and (A_2, ϵ_2, T_2); surface resistances: $\mathcal{R}_{s1} = (1 - \epsilon_1)/(A_1 \epsilon_1)$ and $\mathcal{R}_{s2} = (1 - \epsilon_2)/(A_2 \epsilon_2)$; definition of total radiative resistance: $\mathcal{R}_{\text{total}} = \mathcal{R}_{s1} + \mathcal{R}_{12} + \mathcal{R}_{s2}$; units of radiative resistance: m^{-2};

Lecture 3

Examples of net radiative exchange relations between: 1) two infinite parallel isothermal gray planes, 2) two long concentric isothermal gray circular cylinders, 3) two concentric isothermal gray spheres; see Maple worksheets on Web and Table 13.3 of text; discuss systems with single radiation shield; show the equivalent radiative "circuit" with nodes and resistors. Final Exam, 1996 with Maple R4 solutions which are on the Web will be available through the Engineering Photocopy Center.

Radiation Sections from Chapters 12 and 13;

Chapter 12: 3, 3.1, 3.2, 3.3, 5, 5.1, 5.2, 5.3, 6

Chapter 13: 1, 1.2, 2, 3, 3.3, 3.4, 3.5, 4
