ECE 309 M.M. Yovanovich

Week 7

Lecture 1

- Radiation View Factor
- Some examples of finding relationships for F_{12} or F_{21}
- Radiation exchange between two isothermal, gray surfaces: A_1, ϵ_1, T_1 and A_2, ϵ_2, T_2:

$$\dot{Q}_{12} = \frac{E_{b1} - E_{b2}}{R_{total}}$$

where

$$R_{total} = R_{s1} + R_{12} + R_{s2} = \frac{1-\epsilon_1}{A_1\epsilon_1} + \frac{1}{A_1F_{12}} + \frac{1-\epsilon_2}{A_2\epsilon_2}$$

and $A_1F_{12} = A_2F_{21}$.

- For black surfaces: $\epsilon_1 = 1, \epsilon_2 = 1$, and $R_{s1} = 0, R_{s2} = 0$.
- Radiative thermal circuit: nodes $(E_{b1}, E_{b2}, J_1, J_2)$ and resistors (R_{s1}, R_{s2}, R_{12}), and throughput $\dot{Q}_{12}$. Nodes J_1, J_2 are called radiosities. For $\epsilon_1 = 1, J_1 = E_{b1}$ and for $\epsilon_2 = 1, J_2 = E_{b2}$

- Radiative exchange relation for two infinite parallel isothermal planes.

- Radiative exchange relation for two infinitely long isothermal concentric cylinders.

- Radiative exchange relation for two isothermal concentric spheres.

- Radiative exchange relation between small isothermal gray convex surface and its large surroundings:

$$\dot{Q}_{12} = \epsilon_1 A_1 \sigma (T_1^4 - T_2^4)$$

- Radiative Conductance $h_{rad}\,[W/(m^2 \cdot K)]$.

$$h_{rad} = \frac{\dot{Q}_{12}}{A_1\,(T_1 - T_2)}$$

In general, it depends on several parameters:

$$h_{rad} = f(A_1, A_2, \epsilon_1, \epsilon_2, F_{12}, T_1, T_2)$$

For a small gray convex geometry in a larger enclosure, $A_2 >> A_1$ and

$$h_{rad} = \epsilon_1 \sigma (T_1^2 + T_2^2)(T_1 + T_2)$$

See calculations in notes to show magnitude of h_{rad} for $\epsilon_1 = 1, T_2 = 300\,K$ and $\Delta T = (T_1 - T_2) = 1, 10, 100\,K$.

Lecture 2

- Radiative shield(s).
- Very thin, metallic, having high thermal conductivity such as a clean, polished aluminum foil. The conduction resistance is negligible. $\Delta T_{shield} \approx 0$. The shield has one temperature.
- System has two isothermal gray surfaces: A_1, ϵ_1, T_1 and A_2, ϵ_2, T_2. The space between the surfaces is a vacuum. A radiative shield is placed between the two surfaces. The system consists of two enclosures connected by the shield.

- At steady-state, the shield attains the temperature T_3 such that $T_1 > T_3 > T_2$. The temperature depends on several system parameters. In general the shield has two sides with different emissivities, $\epsilon_{s1}, \epsilon_{s2}$, facing A_1, A_2 respectively.

- System with one shield can be modeled as having six radiative resistors in series: $R_{s1}, R_{13}, R_{ss1}, R_{ss2}, R_{32}, R_{s2}$, and seven radiative nodes: $E_{b1}, J_1, J_{s1}, E_{b3}, J_{s2}, J_2, E_{b2}$
- Net radiative heat exchange between the gray surfaces with the shield is reduced, and it is obtained from

$$\dot{Q}_{sys} = \frac{E_{b1} - E_{b2}}{R_{sys}} = \frac{\sigma\,(T_1^4 - T_2^4)}{R_{s1} + R_{13} + R_{ss1} + R_{ss2} + R_{32} + R_{s2}}$$

In general, the radiative resistors are

$$R_{s1} = \frac{1 - \epsilon_1}{A_1 \epsilon_1}, \quad R_{s2} = \frac{1 - \epsilon_2}{A_2 \epsilon_2}, \quad R_{13} = \frac{1}{A_1 F_{13}}, \quad R_{32} = \frac{1}{A_3 F_{32}}$$

and for the shield:

$$R_{ss1} = \frac{1 - \epsilon_{s1}}{A_{s1} \epsilon_{s1}}, \quad R_{ss2} = \frac{1 - \epsilon_{s2}}{A_{s2} \epsilon_{s2}}$$

For large parallel surfaces: $A_1 = A_2 = A_{s1} = A_{s2} = A$ and $F_{13} = F_{32} = 1$.
For long concentric circular cylinders the areas are different and $F_{13} = F_{32} = 1$.
For concentric spheres the areas are different and $F_{13} = F_{32} = 1$.

- Multiple shields can be handled in a similar manner. Two shields create three connected enclosures.

Lecture 3

- Hand out crib sheet. It will be revised slightly for the midterm exam.

- Thermodynamics. Read Chapters 1 and 2.
- Terminology, Definitions and Symbols.
- Schematic of a system and its environment (surroundings) forming an isolated system.
- System boundary (real or imaginary, fixed or movable) must be identified at all times.
- System interacts with its surroundings by transfer of energy in the form of *Work* or *Heat* across its boundaries.
- Symbols: E, W, Q which represent:
- Energy $[J]$, Work (displacement or shaft (torque)) $[J]$, and Heat $[J]$.

- System:

– Any specified collection of matter.
– All systems possess properties.
– Thermodynamics deals with these properties as the system interacts with its surroundings through *Work* and *Heat* crossing the system boundaries.
– Work and Heat are not properties of the system. They are forms of energy which cross the system boundaries.

- Some Properties of Systems.

– All are based on: Length, $[m]$, Mass, $[kg]$ and Time, $[s]$
– Mass: M $[kg]$
– Volume: V $[m^3]$
– Pressure: P $[N/m^2, Pa]$
– Temperature: T $[K]$
– Mass density: $\rho = M/V$ $[kg/m^3]$
– Specific volume: $v = V/M$ $[m^3/kg] = 1/\rho$
– Internal energy: U $[J]$
– Specific internal energy: $u = U/M$ $[J/kg]$
– Enthalpy: $H = U + PV$ $[J]$
– Specific enthalpy: $h = H/M = u + Pv$ $[J/kg]$
There are many other properties of systems.
