III. CONTINUUM TRANSPORT

The carrier particles of the vast majority of transport processes have sufficiently short mean free paths that they fall within the continuum regime. Transport is induced by difference(s) in thermodynamic potential(s). Thus a region undergoing a transport process cannot be in an extensive equilibrium state.[14] However, the continuum assumption assures that as carrier particles move from region to region and effect transport they will be continuously relaxed through collisions toward an equilibrium value in each local region. Thus the *continuum* assumption is sufficient to assure *local equilibrium states*.[14] The properties of systems undergoing a continuum transport process are equilibrium properties at each point. The spatial property variations are continuous; continuum transport can be described in terms of local property derivatives. Furthermore, most continuum transport processes occur with or without net carrier particle transport. (Mass and charge transport are exceptions, see below.) That is, transport results from the gradient in the transported quantity rather than from a net flux of carrier particles. Consider the following general development.

Continuum Transport without a Net Carrier Particle Flux. Let $\hat{\Gamma}(x)$ be the mean value of a conserved quantity *per carrier particle* at position x and $\dot{n}''(x)$ the flux of carrier particles. Since local equilibrium exists at position x, the particle flux is isotropic at that point (in a stationary system). Thus the flux of carrier particles in positive x direction is equal to the flux of carrier particles in the negative x direction at each point. If the system is in an extensive equilibrium state, the flux of the conserved quantity is the same in all directions.

$$j''_{+x} = j''_{-x} = \dot{n}''(x)\hat{\Gamma}(x)$$

Now consider how this changes when the system is not in extensive equilibrium. Let λ_x be the component of the mean free path in the x direction for particles moving in either the positive or the negative x direction at point x. Then

[14]The distinction between an extensive and an intensive (local) equilibrium state is discussed in Unit IA, see definitions 28 and 31.

Ans. 13. $\dot{e}''_b(300\ K) = \sigma T^4 = 5.668 \cdot 10^{-8} W/(m^2K^4) \cdot (300\ K)^4 = 459.1\ W/m^2$; $\dot{e}''_b(1000\ K) = 5.668 \cdot 10^4 W/m^2$; $\dot{e}''_b(3000\ K) = 4.591 \cdot 10^6 W/m^2$, $\dot{e}''_b(10{,}000\ K) = 5.668 \cdot 10^8 W/m^2$.

Ans. 14. The rate of radiation is governed by the surface temperature and emittance according to $\dot{Q} = A\epsilon\sigma T^4$. Thus the respective steady state temperatures are

$$T_1 = \left(\frac{\dot{Q}}{A\epsilon_1\sigma}\right)^{1/4} = \left[\frac{450\ W}{2m^2 \cdot 0.05 \cdot 5.668 \cdot 10^{-8} W/(m^2K^4)}\right]^{1/4} = 531\ K; \quad T_2 = 254\ K.$$

The higher temperature may be too high for some components. The system may be designed to operate at any desired temperature level between these two by using an appropriate surface treatment or radiator area.