PROBLEM 6.42

KNOWN: Form of Nusselt number for flow of air or a dielectric liquid over components of a circuit card.

FIND: Ratios of time constants associated with intermittent heating and cooling. Fluid that provides faster thermal response.

PROPERTIES: Prescribed. Air: $k = 0.026$ W/m·K, $\nu = 2 \times 10^{-5}$ m^2/s, $Pr = 0.71$. Dielectric liquid: $k = 0.064$ W/m·K, $\nu = 10^{-6}$ m^2/s, $Pr = 25$.

ANALYSIS: From Eq. 5.7, the thermal time constant is

$$\tau_t = \frac{\rho \forall c}{\bar{h} A_s}$$

Since the only variable that changes with the fluid is the convection coefficient, where

$$\bar{h} = \frac{k}{L}\overline{Nu}_L = \frac{k}{L} C Re_L^m Pr^n = \frac{k}{L} C \left(\frac{VL}{\nu}\right)^m Pr^n$$

the desired ratio reduces to

$$\frac{\tau_{t,air(a)}}{\tau_{t,dielectric(d)}} = \frac{\bar{h}_d}{\bar{h}_a} = \frac{k_d}{k_a}\left(\frac{\nu_a}{\nu_d}\right)^m \left(\frac{Pr_d}{Pr_a}\right)^n$$

$$\frac{\tau_{t,a}}{\tau_{t,d}} = \frac{0.064}{0.026}\left(\frac{2\times10^{-5}}{10^{-6}}\right)^{0.8}\left(\frac{25}{0.71}\right)^{0.33} = 88.6$$

Since its time constant is nearly two orders of magnitude smaller than that of the air, the dielectric liquid is clearly the fluid of choice. <

COMMENTS: The accelerated testing procedure suggested by this problem is commonly used to test the durability of electronic packages.