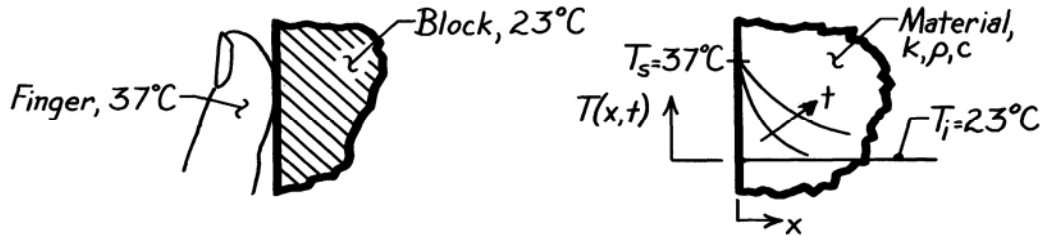


### PROBLEM 5.66

**KNOWN:** Two large blocks of different materials – like copper and concrete – at room temperature, 23°C.

**FIND:** Which block will feel cooler to the touch?

**SCHEMATIC:**



**ASSUMPTIONS:** (1) Blocks can be treated as semi-infinite solid, (2) Hand or finger temperature is 37°C.

**PROPERTIES:** Table A-1, Copper (300K):  $\rho = 8933 \text{ kg/m}^3$ ,  $c = 385 \text{ J/kg}\cdot\text{K}$ ,  $k = 401 \text{ W/m}\cdot\text{K}$ ; Table A-3, Concrete, stone mix (300K):  $\rho = 2300 \text{ kg/m}^3$ ,  $c = 880 \text{ J/kg}\cdot\text{K}$ ,  $k = 1.4 \text{ W/m}\cdot\text{K}$ .

**ANALYSIS:** Considering the block as a semi-infinite solid, the heat transfer situation corresponds to a sudden change in surface temperature, Case 1, Figure 5.7. The sensation of coolness is related to the heat flow from the hand or finger to the block. From Eq. 5.58, the surface heat flux is

$$q_s''(t) = k(T_s - T_i) / (\pi \alpha t)^{1/2} \quad (1)$$

or

$$q_s''(t) \sim (k\rho c)^{1/2} \quad \text{since} \quad \alpha = k/\rho c. \quad (2)$$

Hence for the same temperature difference,  $T_s - T_i$ , and elapsed time, it follows that the heat fluxes for the two materials are related as

$$\frac{q_{s,\text{copper}}''}{q_{s,\text{concrete}}''} = \frac{(k\rho c)_{\text{copper}}^{1/2}}{(k\rho c)_{\text{concrete}}^{1/2}} = \frac{\left[ 401 \frac{\text{W}}{\text{m}\cdot\text{K}} \times 8933 \frac{\text{kg}}{\text{m}^3} \times 385 \frac{\text{J}}{\text{kg}\cdot\text{K}} \right]^{1/2}}{\left[ 1.4 \frac{\text{W}}{\text{m}\cdot\text{K}} \times 2300 \frac{\text{kg}}{\text{m}^3} \times 880 \frac{\text{J}}{\text{kg}\cdot\text{K}} \right]^{1/2}} = 22.1$$

Hence, the heat flux to the copper block is more than 20 times larger than to the concrete block. The *copper* block will therefore feel noticeably cooler than the concrete one.