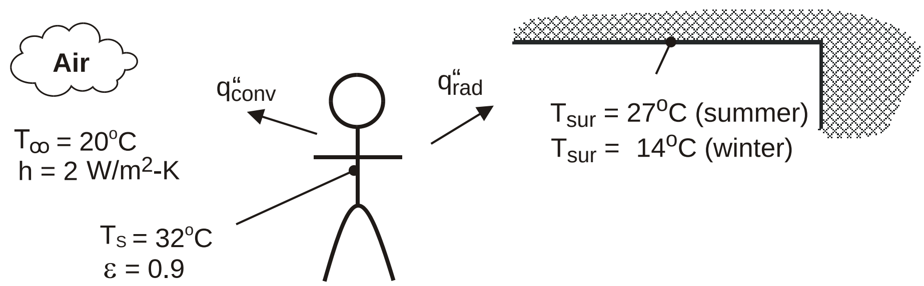
PROBLEM 1.23

KNOWN: Air and wall temperatures of a room. Surface temperature, convection coefficient and emissivity of a person in the room.

FIND: Basis for difference in comfort level between summer and winter. Ratio of thermal convection resistance to thermal radiation resistance in summer and winter.

SCHEMATIC:



ASSUMPTIONS: (1) Person may be approximated as a small object in a large enclosure.

ANALYSIS: Thermal comfort is linked to heat loss from the human body, and a *chilled* feeling is associated with excessive heat loss. Because the temperature of the room air is fixed, the different summer and winter comfort levels cannot be attributed to convection heat transfer from the body. In both cases, the convection heat flux is

Summer and Winter: $q''_{conv} = h\left(T_s - T_\infty\right) = 2\ \text{W/m}^2 \cdot \text{K} \times 12\ ^\circ\text{C} = 24\ \text{W/m}^2$

However, the heat flux due to radiation will differ, with values of

Summer: $q''_{rad} = \varepsilon\sigma\left(T_s^4 - T_{sur}^4\right) = 0.9 \times 5.67 \times 10^{-8}\,\text{W/m}^2 \cdot \text{K}^4 \left(305^4 - 300^4\right)\text{K}^4 = 28.3\ \text{W/m}^2$

Winter: $q''_{rad} = \varepsilon\sigma\left(T_s^4 - T_{sur}^4\right) = 0.9 \times 5.67 \times 10^{-8}\,\text{W/m}^2 \cdot \text{K}^4 \left(305^4 - 287^4\right)\text{K}^4 = 95.4\ \text{W/m}^2$

There is a significant difference between winter and summer radiation fluxes, and the chilled condition is attributable to the effect of the colder walls on radiation. <

From Eq. 1.11, the thermal resistance due to convection is

$$R_{t,conv} = \Delta T / q_{conv} = \left(T_s - T_\infty\right) / q''_{conv} A$$

and the thermal resistance due to radiation is

$$R_{t,rad} = \Delta T / q_{rad} = \left(T_s - T_{sur}\right) / q''_{rad} A$$

Continued…

Thus the ratio of resistances is

$$\frac{R_{t,conv}}{R_{t,rad}} = \frac{\left(T_s - T_\infty\right)/q''_{conv}}{\left(T_s - T_{sur}\right)/q''_{rad}}$$

Summer:

$$\frac{R_{t,conv}}{R_{t,rad}} = \frac{\left(32-20\right)\ \text{K}/24\ \text{W/m}^2}{\left(32-27\right)\ \text{K}/28.3\ \text{W/m}^2} = 2.83 \qquad <$$

Winter:

$$\frac{R_{t,conv}}{R_{t,rad}} = \frac{\left(32-20\right)\ \text{K}/24\ \text{W/m}^2}{\left(32-14\right)\ \text{K}/95.4\ \text{W/m}^2} = 2.65 \qquad <$$

COMMENTS: (1) For a representative surface area of A = 1.5 m^2, the heat losses are q_{conv} = 36 W, $q_{rad(summer)}$ = 42.5 W and $q_{rad(winter)}$ = 143.1 W. The winter time radiation loss is significant and if maintained over a 24 h period would amount to 2,950 kcal. (2) The convection resistance is larger than the radiation resistance but they are the same order of magnitude. There isn't much difference in the resistances between summer and winter conditions; the main difference is the larger *temperature difference* through which radiation occurs in the winter as compared to summer.