Table 14.6 Coefficients of Convection for Dry Air and Bare Skin

Wind Speed (m/s)	Convective Coefficient $W/(m^2 \cdot °C)$
1	15
2	22
3	26
4	28.5
5	32

Convection

Mathematical analysis of convection is quite difficult, but a relatively simple approximation is useful in some cases. We can define a **coefficient of convection** (h) for various conditions, such as for dry air moving at various speeds across skin. The rate of heat flow due to convection when a fluid moves along a surface is proportional to the surface area and to the temperature difference:

Rate of convective heat flow:

$$\mathcal{P} = hA\,\Delta T \qquad (14\text{-}19)$$

Here A is the surface area over which the fluid moves, ΔT is the temperature difference between the surface and the fluid, and h is the coefficient of convection.

If the fluid is at a higher temperature than the surface, the heat flows from the fluid to the surface. If the surface is warmer, then the heat flows from the surface to the fluid. Equation (14-19) can be applied to air moving over skin with the help of Table 14.6, which lists convective coefficients for dry air moving over bare skin.

Example 14.16

Roller Blading in Still Air

A young woman is roller blading in still, dry air at a temperature of 30.0°C. She is moving along at 1.0 m/s and has approximately 0.90 m^2 of skin exposed to the breeze. What is the rate of convective heat flow from her skin, at a temperature of 35.0°C, to the air?

Strategy The roller blader is moving at 1.0 m/s along the road, but we can consider her to be still and the air to be moving past her at 1.0 m/s.

Given: $T_{\text{fluid}} = 30.0°\text{C}$; $T_{\text{surface}} = 35.0°\text{C}$; surface area of bare skin exposed is $A = 0.90\ \text{m}^2$

Look up: coefficient of convection h for dry air and bare skin at wind speed of 1.0 m/s

Find: rate of heat flow, $\mathcal{P}$

Solution From Table 14.6, the coefficient of convection h for dry air and bare skin at a wind speed of 1.0 m/s is

$$h = 15\,\frac{\text{W}}{\text{m}^2\cdot°\text{C}}$$

To find the rate of heat flow by convection, we use the equation

$$\mathcal{P} = hA\,\Delta T$$

Substituting values yields

$$\mathcal{P} = 15\,\frac{\text{W}}{\text{m}^2\cdot°\text{C}} \times 0.90\ \text{m}^2 \times (30.0°\text{C} - 35.0°\text{C}) = -68\ \text{W}$$

Heat flows from her skin at a rate of 68 W.

Discussion The result can only be considered an estimate because the speed at which air moves past the skin is not a uniform 1.0 m/s. Due to the complicated pattern of airflow around the roller blader's body, the air moves faster past some surfaces than others.

In addition to convection, the body loses heat due to radiation (Section 14.8). This heat loss estimate represents only *part* of the heat lost by the body.

Practice Problem 14.16 A Sailor Standing on the Bow of a Ship

A sailor on an America's Cup racing yacht is wearing shorts and no shirt; the area of exposed skin is 1.3 m^2. The apparent wind (speed of the air relative to the sailor's body) is 5.0 m/s. What is the approximate rate of convective heat loss if his skin is at 35.0°C and the air temperature is 29.0°C? Assume that the air is dry.

Problems

103. A marathon runner is moving along the road at 2.0 m/s in still air that is at a temperature of 29.0°C. His surface area is 1.4 m^2, of which approximately 85% is exposed to the air. What is the rate of convective heat loss from his skin, at a temperature of 35.0°C, to the outside air?

104. A small child is being pulled in a cart behind a bicycle that is traveling at 1.80 m/s in still air at a temperature of 25.0°C. If the exposed skin area of the child is 0.500 m^2, what is the rate of convective heat loss from the child's skin? The convective coefficient for that wind speed is 21.0 W/(m^2·°C) and the child's skin is at 35.0°C.

Answers to Practice Problems

14.16 250 W