* 1. **Heat transfer by Convection**

Convection is the mode of energy transfer between a solid surface and the adjacent liquid or gas that is in motion, and it involves the combined effects of *conduction \*and *fluid motion.* The faster the fluid motion, the greater the convection heat transfer. In the absence of any bulk fluid motion, heat transfer between a solid surface and the adjacent fluid is by pure conduction. The presence of bulk motion of the fluid enhances the heat transfer between the solid surface and the fluid, but it also complicates the determination of heat transfer rates. Consider the cooling of a hot block by blowing cool air over its top surface (Fig. 5). Energy is first transferred to the air layer adjacent to the block by conduction. This energy is then carried away from the surface by convection, that is, by the combined effects of conduction within the air that is due to random motion of air molecules and the bulk or macroscopic motion of the air that removes the heated air near the surface and replaces it by the cooler air. Convection is called **forced convection** if the fluid is forced to flow over the surface by external means such as a fan, pump, or the wind. In contrast, convection is called **natural** (or **free**) **convection** if buoyancy forces that are induced by density differences due to the variation cause the fluid motion

of temperature in the fluid (Fig. 6).

 

**FIGURE 5** Heat transfer from a hot **FIGURE 6** The cooling of a boiled egg by forced and natural convection surface to air by convection

For example, in the absence of a fan, heat convection since any motion in the air in this case will be due to the rise of the warmer (and thus lighter) air near the surface and the fall of the cooler (and thus heavier) air to fill its place. Heat transfer between the block and the surrounding air will be by conduction if the temperature difference between the air and the block is not large enough to overcome the resistance of air to movement and thus to initiate natural convection currents. Heat transfer processes that involve *change of phase* of a fluid are also considered to be convection because of the fluid motion induced during the process, such as the rise of the vapor bubbles during boiling or the fall of the liquid droplets during condensation. Despite the complexity of convection, the rate of *convection heat transfer* is observed to be proportional to the temperature difference, and is conveniently expressed by **Newton’s law of cooling** as

 (8)

where *h* is the ***convection heat transfer coefficient***in W/m**2** · °C or Btu/h · ft**2** · °F, *As* is the surface area through which convection heat transfer takes place, *Ts* is the surface temperature, and *T*$\infty $ is the temperature of the fluid sufficiently far from the surface. Note that at the surface, the fluid temperature equals the surface temperature of the solid.

**Example**

A 2-m-long, 0.3-cm-diameter electrical wire extends across a room at 15°C, as

shown in Fig. blow . Heat is generated in the wire as a result of resistance heating, and the surface temperature of the wire is measured to be 152°C in steady operation. Also, the voltage drop and electric current through the wire are measured to be 60 V and 1.5 A, respectively. Disregarding any heat transfer by radiation, determine the convection heat transfer coefficient for heat transfer between the outer surface of the wire and the air in the room.



**SOLUTION**

The convection heat transfer coefficient for heat transfer from an electrically heated wire to air is to be determined by measuring temperatures when steady operating conditions are reached and the electric power consumed.

***Assumptions***

**1** Steady operating conditions exist since the temperature readings do not change with time. **2** Radiation heat transfer is negligible.

***Analysis***

When steady operating conditions are reached, the rate of heat loss

from the wire will equal the rate of heat generation in the wire as a result of

resistance heating. That is,



The surface area of the wire is

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Newton’s law of cooling for convection heat transfer is expressed as

 

Disregarding any heat transfer by radiation and thus assuming all the heat loss

from the wire to occur by convection, the convection heat transfer coefficient is

determined to be

