HEATING A FRYING PAN'S HANDLE

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Reference: Daniel V. Schroeder, *An Introduction to Thermal Physics*, (Addison-Wesley, 2000) - Problem 1.60.

Here's another simple example of thermal conductivity. Suppose we have a frying pan heated to 200°C on a stove. Assuming that the iron handle (length 20 cm) of the pan starts off at room temperature of 20°C, about how long would it take for the handle to reach a temperature where it's too hot to hold with your bare hand? We're given that the density of iron is 7.9×10^{3} kg m^{-3}, its specific heat capacity is $c=450$ J kg^{-1}K^{-1} and (on page 39) the thermal conductivity of iron is $k_t = 80$ W m^{-1}K^{-1}.

The rate of heat flow is

$$\frac{Q}{\Delta t}=k_tA\frac{\Delta T}{\Delta x} \tag{0.1}$$

where A is the cross-sectional area of the handle.

Taking $\Delta T=200-20=180$ K and $\Delta x=0.2$ m, we can assume that all of the heat that flows along the handle goes into heating up the iron (which isn't quite true of course, since some of the heat will dissipate into the surrounding air, but given that the thermal conductivity of air is very low compared to that of iron, we can neglect it). The rate at which heat flows into the handle is then

$$\frac{Q}{\Delta t}=80\frac{180}{0.2}A=7.2\times10^{4}A\text{ W} \tag{0.2}$$

The mass of iron that is being heated (assuming a cylindrical handle) is

$$m=(0.2A)(7900)=1580A\text{ kg} \tag{0.3}$$

In time Δt, therefore, the temperature will increase by

$$\Delta T_{heat} = \frac{Q}{mc} \tag{0.4}$$

$$= \frac{7.2\times10^{4}A}{(1580)(450)A}\Delta t \tag{0.5}$$

$$= 0.1\Delta t \tag{0.6}$$

A temperature of around 80°C is probably uncomfortably hot, so we're looking for $\Delta T_{heat} \approx 60$ K so it would take around 10 minutes for the handle to heat up that much.