8.2.3 Cooling of coffee

MO2.4

A cup of coffee cools because of heat transfer with the surrounding air. This cooling process can be modeled using thermodynamics. In particular, the First Law of Thermodynamics relates changes in energy in a system to heat transfer into the system and work done by the system, specifically,

$$\frac{\mathrm{d}E}{\mathrm{d}t} = \dot{Q} - \dot{W} \tag{8.13}$$

where E is the energy in the system, $\dot{Q}$ is the rate of heat transfer into the system, and $\dot{W}$ is the rate at which work is done by the system.

In this case, our system is the coffee and the cup with temperature $T_c\,(t)$. The time rate of change of energy in the coffee can be related to the time rate of change of T_c, specifically,

$$\frac{\mathrm{d}E}{\mathrm{d}t} = m_c c_c \frac{\mathrm{d}T_c}{\mathrm{d}t} \tag{8.14}$$

where m_c is the mass of coffee in the cup and c_c is called the specific heat capacity of coffee.

The heat transfer rate into the cup can be estimated using the following model,

$$\dot{Q} = hA\,(T_{\text{out}} - T_c) \tag{8.15}$$

where h is the heat transfer coefficient, A is the surface area of the cup (including the top surface of the coffee), and T_{out} is the temperature of the environment. $h \geq 0$ is positive and depends on various factors including the material of the cup and if there is air motion outside the cup (e.g. a windy day or someone blows on the coffee to help cool it). Note that when $T_{\text{out}} < T_c$, then $\dot{Q} < 0$ which indicates the heat transfer is *out* of the cup into the atmosphere.

Finally, since there is nothing moving, there is no work being done, i.e. $\dot{W} = 0$.

Combining Equations (8.14) and (8.15) gives the following model differential equation,

(8.16)

$\mathrm{d}T_c$

Discussions

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How was the heat capacity of the system deri
HusamMalkawi
3

My chart seems wrong I applied my understar
__kiwi__
6

Cooling time in minutes or seconds? In the vic
SilVanBrummen
6

From equation 8.16 to plot Fig.8.4 No preview
Rockstar_kath
3

$$m_c c_c \frac{\mathrm{d}T_c}{\mathrm{d}t} = hA\left(T_{\text{out}} - T_c\right)$$

In Figure 8.4, the variation of the temperature in time is shown for two outside air temperature (25 and 5 degrees C), with the other parameters set as,

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$$T_c(0) = 85^\circ\mathrm{C}, \quad m_c = 0.35\,\mathrm{kg}, \quad c_c = 4200\,\mathrm{J}/(\mathrm{kgC}), \tag{8.1}$$

$$h = 5\,\mathrm{W}/(\mathrm{m}^2\mathrm{C}) \quad A = 0.04\,\mathrm{m}^2 \tag{8.1}$$

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go to the next example.

So we're going to look at the cooling of