Chapter 5: Convection

1. Given: A pot of water, 20 cm in diameter and 15 cm tall, is kept at boil on a stove. $h_{top} = h_{side} = 25$ W/m^{2}K, $T_\infty = 22$ °C.

   Find: Heat loss due to convection

   Assumptions: Bottom surface has no convective heat loss.

   Solution:
   Heat loss by convection is given by:

   $$q_{conv} = -hA(T_{pot} - T_\infty).$$

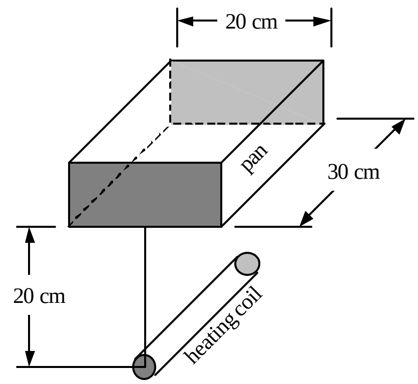
   Area of the pot is:

   $$\begin{aligned} A &= \pi d^2/4 + \pi dh \\ &= \pi(0.2^2)/4 + \pi(0.2)(0.15) \\ &= 0.126 \text{ m}^2 \end{aligned}$$

   Convective heat loss is:

   $$\begin{aligned} q_{conv} &= -hA(T_{pot} - T_\infty). \\ &= -(25)(0.126)(100 - 22) \\ &= \mathbf{-245\ W} \end{aligned}$$

Chapter 6: Radiation



1. Given: A pan above a heating coil as shown in figure.
   T_{coil} = 1000 °C, T_{pan} = 400 °C
   ε_{Al} = 0.7, α_{Al} = 0.6, ε_{steel} = 0.25, α_{steel} = 0.5, ε_{coil} = 0.8
   r_{coil} = 3 mm

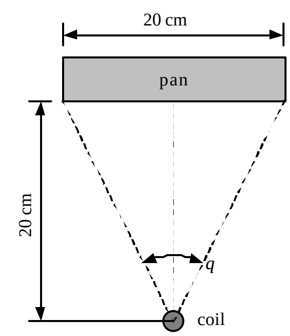
   Find: Amount of heat transfer from coil to pan for a) aluminum pan and b) steel pan.

   Assumptions: Convection and conduction are neglected. Radiation emitted by the pan is neglected.

   Solution:
   The heat given off by the coil is given by:
   $$q_{emitted} = \varepsilon_{coil}\,\sigma A_{coil}\,T_{coil}^4$$

   Of that amount, the portion that reaches the pan is:
   $$q_{incident} = F_{coil \to pan}\,q_{emitted}$$

   Furthermore, only a portion of the incident radiation is absorbed by the pan. The total heat that is absorbed by the pan is:
   $$\begin{aligned} q_{absorbed} &= \alpha_{\text{pan}}\,q_{incident} \\ &= \alpha_{\text{pan}}\,F_{coil \to pan}\,\varepsilon_{coil}\,\sigma A_{coil}\,T_{coil}^4 \end{aligned}$$



   The shape factor from coil to the pan is determined by the geometry, as shown in the figure to the right. The coil emits uniformly in all directions (360°), but only a portion defined by angle θ reaches the pan. The angle is equal to:
   $$\begin{aligned} \theta &= 2\tan^{-1}(10/20) \\ &= 53.13° \end{aligned}$$

   The shape factor is:
   $$\begin{aligned} F_{coil \to pan} &= 53.13 / 360 \\ &= 0.1476 \end{aligned}$$

   The area of the coil is:
   $$\begin{aligned} A_{coil} &= 2\pi rL \\ &= 2\pi(0.003)(0.3) \\ &= 0.00565\ \text{m}^2 \end{aligned}$$

   The heat absorbed by each type of pan is:
   $$\begin{aligned} q_{absorbed,\,Al} &= \alpha_{\text{Al}}\,F_{coil \to pan}\,\varepsilon_{coil}\,\sigma A_{coil}\,T_{coil}^4 \\ &= (0.6)(0.1476)(0.8)(5.67\times10^{-8})(0.0028)(1273.15^4) \\ &= \mathbf{59.6\ W} \end{aligned}$$
   ← T_{coil} must be in Kelvins

   $$\begin{aligned} q_{absorbed,\,steel} &= \alpha_{\text{steel}}\,F_{coil \to pan}\,\varepsilon_{coil}\,\sigma A_{coil}\,T_{coil}^4 \\ &= (0.5)(0.1476)(0.8)(5.67\times10^{-8})(0.0028)(1273.15^4) \\ &= \mathbf{19.7\ W} \end{aligned}$$

Chapter 7: Microwaves

1. Solution: Microwave ovens heat foods by agitating the water molecules in foods. In frozen foods, the molecules are tightly bound and cannot be vibrated until it has melted. This results in highly uneven heating while defrosting frozen foods, as "pockets" of melted water heats rapidly while surrounding frozen areas remain cold. Frozen water has a low thermal conductivity (0.9 W/mK), thus the heat from melted (hot) portions cannot transfer effectively to the still frozen sections. To distribute the heat more evenly and prevent overcooking in some regions, the food must sit for a few minutes to let the heat conduct through the frozen sections, thawing it.