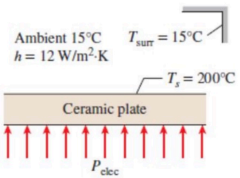
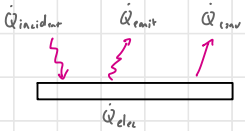
Example

A circular ceramic plate 30 cm in diameter (shown below) can be modelled as a blackbody. It is being heated by an electrical heater.

If the efficiency of the electrical heater to transfer heat to the plate is 80%, determine the electrical power the heater needs to keep the surface temperature of the plate at 200°C

Assumptions:
- Plate – blackbody
- Surface temperature is uniform





$T_\infty = T_{surr} = 15°C + 273 = 288\ [K]$

$T_s = 200°C + 273 = 473\ [K]$

$\dot{Q}_{emit} = \varepsilon \sigma A_s T_s^4$

$= (1)(5.67 \times 10^{-8}\ [W/m^2 \cdot K]) \times \frac{\pi (0.3\ [m])^2}{4} \times (473\ [K])^4$ (blackbody →)

$= 200.61\ [W]$

$\dot{Q}_{incident} = \varepsilon \sigma A_s T_{surr}^4$

$= 1\ (5.67 \times 10^{-8}\ [W/m^2 \cdot K]) \times \frac{\pi (0.3\ [m])^2}{4} \times (288\ [K])^4$

$= 27.57\ [W]$

$\dot{Q}_{conv} = h A_s (T_s - T_\infty)$

$= 12\ [W/m^2 \cdot K] \times \frac{\pi (0.3\ [m])^2}{4} \times (473 - 288\ [K])$

$= 156.9\ [W]$

Energy balance on plate:

$0 = \dot{E}_{generated} + \dot{E}_{in} - \dot{E}_{out}$

$\dot{E}_{gen} = \dot{E}_{out} - \dot{E}_{in}$

$\eta P_{elec} = \dot{Q}_{emit} + \dot{Q}_{conv} - \dot{Q}_{incident}$

$P_{elec} = \frac{\dot{Q}_{emit} + \dot{Q}_{conv} - \dot{Q}_{incident}}{0.8} = \frac{200.61 - 27.57 + 156.9\ [W]}{0.8} = \boxed{412.42\ [W]}$

Electric power required by heater to keep constant 200°C at plate