# ASSIGNMENT #5

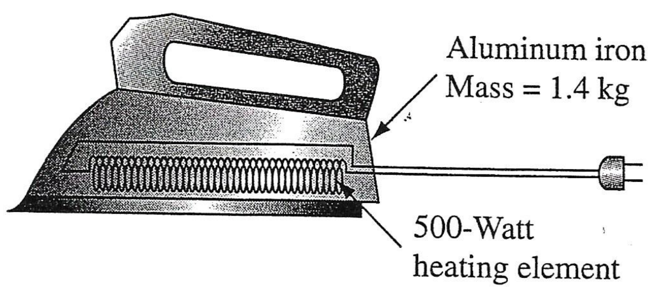
## Lumped System Analysis Problems

5–1 A 0.6-cm-diameter mild steel rod at 38°C is suddenly immersed in a liquid at 93°C with $\bar{h}_c = 110$ W/m$^2$ K. Determine the time required for the rod to warm to 88°C.

5–2 A thin-wall cylindrical vessel (1 m in diameter) is filled to a depth of 1.2 m with water at an initial temperature of 15°C. The water is well stirred by a mechanical agitator. Estimate the time required to heat the water to 50°C if the tank is suddenly immersed in oil at 105°C. The overall heat transfer coefficient between the oil and the water is 284 W/m$^2$ K, and the effective heat transfer surface is 4.2 m$^2$.

5–3 A large, 2.54-cm.-thick copper plate is placed between two air streams. The heat transfer coefficient on one side is 28 W/m$^2$ K and on the other side is 57 W/m$^2$ K. If the temperature of both streams is suddenly changed from 38°C to 93°C, determine how long it will take for the copper plate to reach a temperature of 82°C.

5–4 A 1.4-kg aluminum household iron has a 500-W heating element. The surface area is 0.046 m$^2$. The ambient temperature is 21°C, and the surface heat transfer coefficient is 11 W/m$^2$ K. How long after the iron is plugged in will its temperature reach 104°C?



5–5 Ball bearings are to be hardened by quenching them in a water bath at a temperature of 37°C. You are asked to devise a continuous process in which the balls could roll from a soaking oven at a uniform temperature of 870°C into the water, where they are carried away by a rubber conveyor belt. The rubber conveyor belt, however, would not be satisfactory if the surface temperature of the balls leaving the water is above 90°C. If the surface coefficient of heat transfer between the balls and the water can be assumed to be equal to 590 W/$m^2$ K, (a) find an approximate relation giving the minimum allowable cooling time in the water as a function of the ball radius for balls up to 1.0 cm in diameter, (b) calculate the cooling time, in seconds, required for a ball having a 2.5-cm diameter, and (c) calculate the total amount of heat in watts that would have to be removed from the water bath in order to maintain a uniform temperature if 100,000 balls of 2.5-cm diameter are to be quenched per hour.