Heat Transfer and Industrial Furnaces

1. **A one-dimensional plate of aluminum ($k = 100\ W/m\ ℃, \rho = 2700\ kg/m^3, Cp = 900\ J/kg.℃$) 1 cm thick and initially at 200℃ is suddenly exposed to air environment at $T_\infty = 30℃$ and convection heat transfer coefficient of $500\ W/m^2K$. Calculate the plate temperature 1 min after the plate has been exposed to the environment. How much energy has been removed per unit area from the plate at this time?**

2. **Consider an iron whose base plate is made of 0.5 cm thick aluminum alloy 2024-T6 ($\rho = 277\ kg/m^3, Cp = 875\ J/kg.℃$, and $\alpha = 7.3 * 10^{-5}\ m^2/s$). The base plate has a surface area of $0.03\ m^2$. Initially, the iron is at 140℃ in thermal equilibrium with the ambient air at 22℃. Taking the heat transfer coefficient at the surface of the base plate to be $12\ W/m^2℃$, determine how long it will take for the plate temperature to reach 80℃ after turning it off. Is it realistic to assume the plate temperature to be uniform at all times?**

3. **Stainless steel ball bearings ($\rho = 8085\ kg/m^3$, $k = 15.1\ W/m.℃$, $Cp = 0.480\ kJ/kg.℃$, and $\alpha = 3.91 * 10^{-6}\ m^2/s$) having a diameter of 1.2 cm are to be quenched in water. The balls leave the oven at a uniform temperature of 900℃ and are exposed to air at 30℃ for a while before they are dropped into the water. If the temperature of the balls is not to fall below 850℃ prior to quenching and the heat transfer coefficient in the air is $125\ W/m^2.℃$, determine how long they can stand in the air before being dropped into the water. If 2500 balls are to be quenched per hour, determine the total rate of heat transfer from the balls to the air.**

4. **A thermocouple junction ($k = 20\ W/m.℃, Cp = 400\ J/kg.℃$ and $\rho = 5000\ kg/m^3$) which may be approximated as a sphere is to be used for temperature measurement in a gas stream. The convection coefficient between the junction and the gas is known to be $h = 400\ W/m^2.℃$. Determine the junction diameter needed for the thermocouple to have a time constant of 1 s. If the junction is at 25℃ and is placed in a gas stream that is 200℃, how long will it take for the junction to reach 199℃ ? Calculate total capacity heat.**

5. **A person is found dead at 5 PM in a room whose temperature is 20℃. The temperature of the body is measured to be 25℃ when found, and the heat transfer coefficient is estimated to be $h = 8\ W/m^2.℃$. Modeling the body as a 30 cm diameter, 1.7 m long cylinder ($\rho = 996\ kg/m^3$, $k = 6\ W/m.℃$, $Cp = 4109.3\ J/kg.℃$). If The person was healthy before death with a body temperature of 37℃, estimate the time of death of that person.**

6. **In a production facility, 4-cm-thick large brass plates ($k = 110\ W/m.℃, \rho = 8530\ kg/m^3$, $Cp = 377\ J/kg.℃$, and $\alpha = 33.9 * 10^{-6}\ m^2/s$) that are initially at a uniform temperature of 20℃ are heated by passing them through an oven maintained at 500℃. The plates remain in the oven for a period of 7 min. Taking the convection heat transfer coefficient to be $h = 120\ W/m^2.℃$, determine the surface temperature of the plates when they come out of the oven.**