CANKAYA UNIVERSITY
FACULTY OF ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT
ME 313 HEAT TRANSFER

CHAPTER-5

EXAMPLES

1) A steel ball (c = 0.46 kJ/kg.^{o}C, k = 35 W/m. ^{o}C) 5.0 cm in diameter and initially at a uniform temperature of 450^{o}C is suddenly placed in a controlled environment in which the temperature is maintained at 100^{o}C. The convection heat transfer coefficient is 10 W/m^2.^{o}C. Calculate the time required for the ball to attain a temperature of 150^{o}C.

2) A copper cylinder 10 cm diameter, 20 cm long is removed from liquid nitrogen bath at -196^{o}C and exposed to air at 25^{o}C with convection coefficient of 20 W/m^2.K. Find the time required by cylinder to attain the temperature of -110^{o}C. Take thermophysical properties as c = 380 J/kg.K, ρ = 8800 kg/m^3, k = 360 W/m.K.

3) A plane wall of a furnace is fabricated from plain carbon steel (k = 60 W/m.K, ρ = 7850 kg/m^3, c = 430 J/kg.K) and is of thickness L = 10 mm. To protect it from the corrosive effects of the furnace combustion gases, one surface of the wall is coated with a thin ceramic film. The thermal resistance of the coating per unit surface area is 0.01 m^2.K/W. The opposite surface is well insulated from the surroundings. At the furnace start-up the wall is at an initial uniform temperature of 300 K. The combustion gases enter the furnace at 1300 K providing a convection coefficient of 25 W/m^2.K at the ceramic film. Assume the film has negligible thermal capacitance. How long will it take for the inner surface of the steel to achieve a temperature of 1200 K? What is the temperature of the exposed surface of the ceramic film at this time?

4) A 50 mm thick iron plate is initially at 225^{o}C. Its both surfaces are suddenly exposed to an environment at 25^{o}C with convection coefficient of 500 W/m^2.K.
a) Calculate the center temperature, 2 minutes after the start of exposure.
b) Calculate the temperature at the depth of 10 mm from the surface, after 2 minutes of exposure.
c) Calculate the energy removed from the plate per square meter during this period. Take thermophysical properties of iron plate: k = 60 W/m.K, ρ = 7850 kg/m^3, c = 460 J/kg, α = 1.6x10^{-5} m^2/s.

5) Annealing is a process by which steel is reheated and then cooled to make is less brittle. Consider the reheat stage for a 100-mm-thick steel plate ($\rho = 7830\ kg/m^3$, $c = 550\ J/kg.K$, $k = 48\ W/m.K$) which is initially at a uniform temperature of T_i = 200^{o}C and is to be heated to a minimum temperature of 550^{o}C. Heating is effected in a gas-fired furnace, where products of combustion at T_∞ = 800^{o}C

maintain a convection coefficient of h = 250 W/m^2.K on both surfaces of the plate. How long should the plate be left in the furnace?

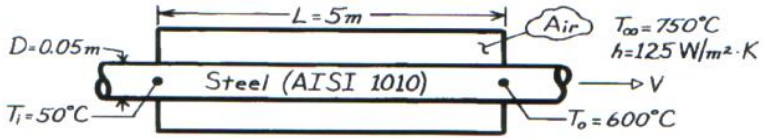
6) A plate of stainless steel (18% Cr, 8% Ni) (k=16.3 W/m.^{o}C, α=0.44x10^{-5} m^2/s) has a thickness of 3.0 cm and is initially uniform in temperature at 500^{o}C. The plate is suddenly exposed to a convection environment on both sides at 40^{o}C with h = 150 W/m^2.^{o}C. Calculate the times for the center and face temperatures to reach 120^{o}C.

7) A slab of copper (k=370 W/m.^{o}C, α=11.23x10^{-5} m^2/s) having a thickness of 3.0 cm is initially at 300^{o}C. It is suddenly exposed to a convection environment on the top surface at 80^{o}C while the bottom surface is insulated. In 6 min the surface temperature drops to 140^{o}C. Calculate the value of convection heat transfer coefficient.

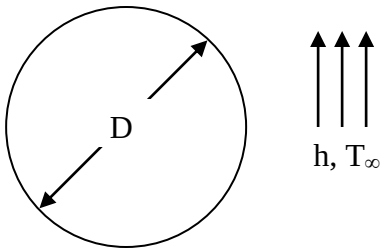
8) A long aluminum cylinder (k=215 W/m.^{o}C, ρ=2700 kg/m^3, c=0.9 kJ/kg. ^{o}C) 5.0 cm in a diameter and initially at 200^{o}C is suddenly exposed to a convection environment at 70^{o}C and h = 525 W/m^2.^{o}C. Calculate the temperature at a radius of 1.25 cm and the heat lost per unit length 1 min after the cylinder is exposed to the environment.

9) A solid iron rod ($\alpha = 2\times10^{-5}$ m^2 / s, k = 60 W / m^o.C) of diameter D = 6 cm, initially at temperature T_i = 800^{o}C, is suddenly dropped into oil bath at T_∞ = 50^{o}C. The heat transfer coefficient between the fluid and solid surface is h = 400 W/m^2.^{o}C.
a) Determine centerline temperature after 10 minutes.
b) How long will it take the centerline temperature to reach 100^{o}C?

10) Cylindrical steel rods (AISI 1010), 50 mm in diameter, are heat treated by drawing them through an oven 5 m long in which air is maintained at 750^{o}C. The rods enter at 50^{o}C and achieve a centerline temperature of 600^{o}C before leaving. For a convection coefficient of 125 W/m^2.K, estimate the speed at which the rods must be drawn through the oven.



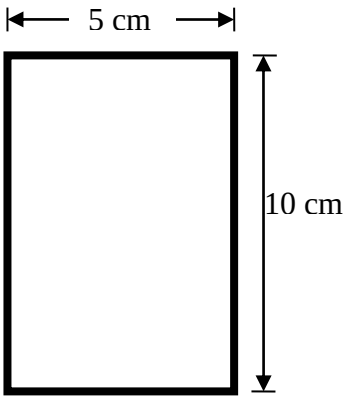
11) An iron sphere (k = 60 W/m^{o}C, c_p = 460 J/kg^{o}C, $\rho = 7850$ kg / m^3, $\alpha = 1.6\times10^{-5}$ m^2 / s) of diameter D = 5 cm is initially at a uniform temperature T_i = 225^{o}C. Suddenly the surface of the sphere is exposed to an ambient at T_∞ = 25^{o}C with heat transfer coefficient h = 500 W/m^2 ^{o}C.
a) Calculate the center temperature t = 2 min after start of cooling.
b) Calculate the energy removed from sphere during this time period.
c) Calculate the temperature at a depth of 1 cm from surface t = 2 min after start of cooling.



12) A large slab has properties of common building brick (k=0.69 W/m.ºC, $\alpha=5.2\times10^{-7}$ m^2/s) and is heated to uniform temperature of 40ºC. The surface suddenly exposed to a convective environment at 2ºC with h = 25 W/m^2 ºC. Calculate the time for the temperature to reach 20ºC at a depth of 8 cm.

13) A semi-infinite aluminum cylinder (k=215 W/m.ºC, $\alpha=8.4\times10^{-5}$ m^2/s) 5 cm in diameter is initially at uniform temperature of 200ºC. It is suddenly subjected to a convection boundary condition at 70ºC with h = 525 $W/m^2.$ºC. Calculate the temperatures at the axis and surface of the cylinder 10 cm from the end 1 min after exposure to the environment.

14) A short aluminum cylinder (k=215 W/m.ºC, $\alpha=8.4\times10^{-5}$ m^2/s) 5.0 cm in diameter and 10 cm long is initially at uniform temperature of 200ºC. It is suddenly subjected to a convection environment at 70ºC, and h = 525 $W/m^2.$ºC. Calculate the temperature at a radial position of 1.25 cm and a distance of 0.625 cm from one end of the cylinder 1 min after exposure to the environment.



$\alpha = 8.4\times10^{-5}\ m^2/s$

$k = 215\ W/m^oC$