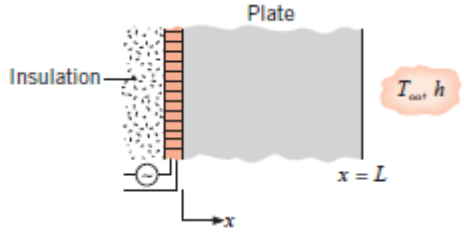
Birzeit University
Mechanical & Mechatronics Engineering Department
Heat Transfer ME 431
Homework # 4 Transient Conduction
Instructor: Dr. Afif Hasan

5.1 Consider a thin electrical heater attached to a plate and backed by insulation. Initially, the heater and plate are at the temperature of the ambient air, $T\infty$. Suddenly, the power to the heater is activated, yielding a constant heat flux q''_o (W/m^2) at the inner surface of the plate.
(a) Sketch and label, on *T- x* coordinates, the temperature distributions: initial, steady-state, and at two intermediate times.
(b) Sketch the heat flux at the outer surface as a function of time.



5.6 Steel balls 12 mm in diameter are annealed by heating to 1150 K and then slowly cooling to 400 K in an air environment for which $T\infty$ = 325 K and h = 20 W/m2 . K. Assuming the properties of the steel to be k = 40 W/m. K, ρ = 7800 kg/m3, and c = 600 J/kg . K, estimate the time required for the cooling process.
5.49 Annealing is a process by which steel is reheated and then cooled to make it less brittle. Consider the reheat stage for a 100-mm-thick steel plate (ρ = 7830 kg/m3, c = 550 J/kg. K, k = 48 W/m. K), which is initially at a uniform temperature of Ti = 200 C and is to be heated to a minimum temperature of 550C. Heating is effected in a gas-fired furnace, where products of combustion at $T\infty$ = 800C maintain a convection coefficient of h = 250 W/m^2. K on both surfaces of the plate. How long the plate should be left in the furnace?
5.61 A long cylinder of 30-mm diameter, initially at a uniform temperature of 1000 K, is suddenly quenched in a large, constant-temperature oil bath at 350 K. The cylinder properties are k = 1.7 W/m.K, c = 1600 J/kg. K, and ρ = 400 kg/m^3, while the convection coefficient is 50 W/m^2. K. (a) Calculate the time required for the surface of the cylinder to reach 500 K.
5.74 Stainless steel (AISI 304) ball bearings, which have uniformly been heated to 850C, are hardened by quenching them in an oil bath that is maintained at 40C. The ball diameter is 20mm, and the convection coefficient associated with the oil bath is 1000 W/m^2. K.
(a) If quenching is to occur until the surface temperature of the balls reaches 100C, how long must the balls be kept in the oil? What is the center temperature at the conclusion of the cooling period?
(b) If 10,000 balls are to be quenched per hour, what is the rate at which energy must be removed by the oil bath cooling system in order to maintain its temperature at 40C?
5.85 Asphalt pavement may achieve temperatures as high as 50C on a hot summer day. Assume that such a temperature exists throughout the pavement, when suddenly a rainstorm reduces the surface temperature to 20C. Calculate the total amount of energy (J/m^2) that will be transferred from the asphalt over a 30-min period in which the surface is maintained at 20C.