Indian Institute of Technology Kharagpur

Department of Chemical Engineering

Advanced Heat Transfer CH61014 (Spring 2025)

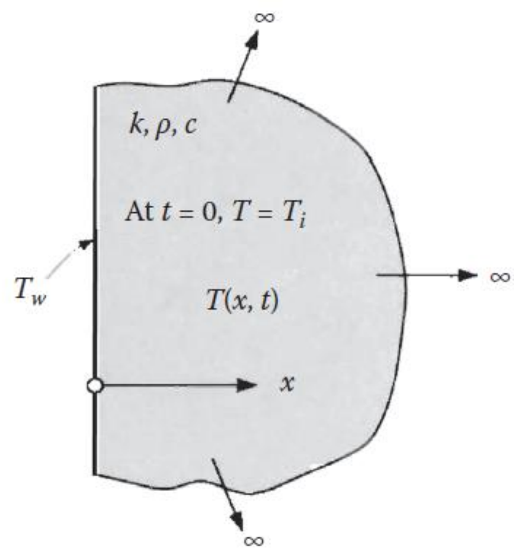
Assignment

1. A slab, extending from $x = 0$ to $x = L$ and of infinite extent in the y and z directions, is initially at a uniform temperature T_i. For times $t \geq 0$, a constant heat flux q'', is applied to the surface at $x = L$, while the surface at $x = 0$ is kept perfectly insulated. Assume that the thermo-physical properties of the slab are constant. Obtain an expression for the unsteady-state temperature distribution $T(x, t)$ in the slab for $t > 0$ using
    a) Separation of Variables
    b) Integral Transform Technique

2. A long solid cylinder of constant thermo-physical properties and radius r_0 is initially at a uniform temperature T_i. For times $t \geq 0$, a constant heat flux q'' is applied to the peripheral surface at $r = r_0$. Obtain an expression for the unsteady-state temperature distribution $T(r, t)$ in the cylinder for $t > 0$ using
    a) Separation of Variables
    b) Integral Transform Technique

3. A solid sphere, $0 \leq r \leq r_0$, of constant thermo-physical properties is initially at a uniform temperature T_i. For times $t \geq 0$, the sphere is heated by applying a constant heat flux q'' to its surface at $r = r_0$. Obtain an expression for the unsteady-state temperature distribution $T(r, t)$ in the sphere for $t > 0$ using
    a) Separation of Variables
    b) Integral Transform Technique

4. Consider a semi-infinite solid, $0 \leq x < \infty$, initially at a uniform temperature T_i. The surface temperature at $x = 0$ is changed to and kept at a constant temperature Tw for times $t \geq 0$. Assume constant thermo-physical properties (k, ρ, c). Obtain an expression for the unsteady-state temperature distribution $T(x, t)$ in the slab using
   a) Finite Fourier Transform
   b) Similarity Method



5. A slab of thickness L is initially at zero temperature. For times $t > 0$, the boundary surface at $x = 0$ is kept at zero temperature, while the surface at $x = L$ is subjected to a time-varying temperature $f(t)$ defined by

$$f(t) = \begin{cases} bt & \text{for} \quad 0 < t < \tau_1 \\ 0 & \text{for} \quad t > \tau_1 \end{cases}$$

   Assume constant thermo-physical properties (k, ρ, c). Obtain an expression for the unsteady-state temperature distribution $T(x, t)$ in the slab using Duhamel's Method.

6. A slab of thickness L is initially at zero temperature. For times $t > 0$, the boundary surface at $x = L$ is kept insulated, while the surface at $x = 0$ is subjected to a time-dependent heat flux $f(t)$ of the functional form:

$$-k \left. \frac{\partial T}{\partial x} \right|_{x=0} = f(t) \equiv \begin{cases} t & \text{for} \quad 0 < t < \tau_1 \\ 0 & \text{for} \quad t > \tau_1 \end{cases}$$

Assume constant thermo-physical properties (k, ρ, c). Using Duhamel's theorem, develop an expression for the temperature distribution $T(x, t)$ in the slab for times:

(i) $t < \tau_1$ and for (ii) $t > \tau_1$.

7. Consider a large solid, $x \geq 0$, initially at the fusion temperature T_f . At $t = 0$, the temperature of the boundary surface at $x = 0$ is raised to T_0 (> T_f) and maintained at that constant temperature for times $t > 0$. Assume constant thermo-physical properties for the liquid phase, and neglect any convective motion in the melt.

   (a) Derive the expressions for the solid–liquid interface location as a function of time (Stefan Condition).

   (b) Obtain exact expressions for both the temperature distribution in the liquid phase by (i) Stefan's exact method and (ii) Integral method.

8. A slab, which extends from $x = 0$ to $x = L$, is initially at a uniform temperature T_∞ at $t = 0$. For times $t \geq 0$, a plane heat source, of strength q"(t) (W/m^2) and located normal to the x-direction at $x = a$ within the slab, releases heat continuously, while the surface at $x = 0$ is kept perfectly insulated and the surface at $x = L$ dissipates heat by convection with a constant heat transfer coefficient h into a fluid medium maintained at the constant temperature T_∞. Assuming constant thermo-physical properties for the slab, obtain an expression for the temperature distribution $T(x, t)$ in the slab for $t > 0$.