1. A plane wall is a composite of two materials, A and B. The wall of material A has uniform heat generation $q = 1.5 \times 10^4 \text{ W/m}^3$, $k_A = 75 \text{ W/m.K}$, and thickness $L_A = 50 \text{ mm}$. The wall material B has no generation with $k_B = 75 \text{ W/m.K}$, and thickness $L_B = 20 \text{ mm}$. The inner surface of material A is well insulated, while the outer surface of material B is cooled by a water stream with $T_w = 30^\circ \text{C}$ and $h = 1000 \text{ W/m}^2 \cdot \text{K}$. Determine the temperature $T_1$ of the insulated surface and the temperature $T_2$ of the cooled surface.

2. Attached to a flat wall of temperature $T_b$ is a plate of thickness $b$, length $L$, and width $W$ (see figure). The plate is made of a highly conductive metal and, as a consequence, its temperature is practically uniform. The plate is bathed on all its exposed sides by a fluid of temperature $T_w$. The heat transfer coefficient has the same value $h$ on all the surfaces wetted by the fluid. The plate described until now is attached to the wall by means of a layer of glue of thickness $t$ and thermal conductivity $k$. Derive an expression for the heat transfer rate that passes from $T_b$ to $T_w$ through the glue-plate system.

3. An uninsulated wire suspended in air generates Joule heating at the rate of $q' = 1 \text{ W/m}$. The wire is a bare cylinder of radius $r = 0.5 \text{ mm}$ and the temperature difference between it and the atmosphere is $30^\circ \text{C}$. It is proposed to cover this wire with a plastic sleeve of electrical insulation, the outer radius of which will be $r_o = 1 \text{ mm}$. The thermal conductivity of the plastic material is $k = 0.35 \text{ W/m.K}$. Will the plastic sleeve improve the wire’s ambient thermal contact, or will it provide a thermal insulation effect?
To verify your answer, calculate the new wire-ambient temperature difference when the wire is encased in plastic.

4. Steam in a heating system flows through tubes whose outer diameter is $D_1=3\text{cm}$ and whose walls are maintained at a temperature of $120^{\circ}\text{C}$. Circular aluminium fins ($k=180\text{W/m}.^{\circ}\text{C}$) of outer diameter $D_2=6\text{cm}$ and constant thickness $t=2\text{mm}$ are attached to the tube. The space between the fins is $3\text{mm}$, and thus there are $200$ fins per unit length of the tube. Heat is transferred to the surrounding air at $T_a=25^{\circ}\text{C}$, with a combined heat transfer coefficient of $60\text{W/m}^2.^{\circ}\text{C}$. Determine the increase in heat transfer from the tube per meter of its length as a result of adding fins.

5. A thin shell made of copper ($k=386\text{W/m}.^{\circ}\text{C}$, $\rho=8900\text{ kg/m}^3$, $C=385\text{J/kg}.^{\circ}\text{C}$) of diameter $5\text{mm}$ and thickness $0.3\text{mm}$ drops off a conveyor vertically down to the ground. The temperature of the shell is initially $75^{\circ}\text{C}$. While it is falling to the ground that is some $30\text{m}$ below, the shell cools by losing heat to the ambient air at $20^{\circ}\text{C}$ via a constant average heat transfer coefficient of $90\text{ W/m}^2.^{\circ}\text{C}$. Determine the temperature of the shell as it hits the ground.

6. Aluminium sheet of dimensions $50\times100\times2\text{ mm}$ is exposed on both sides to an ambient fluid at $25^{\circ}\text{C}$ with an average heat transfer coefficient of $7\text{ W/m}^2.^{\circ}\text{C}$. Is it proper to consider the aluminium ($k=236\text{W/m}.^{\circ}\text{C}$, $\rho=2702\text{ kg/m}^3$, $C=896\text{J/kg}.^{\circ}\text{C}$) sheet as a lumped system for transient analysis? If the answer is yes, determine the time constant of the first order system. If the initial temperature of the plate is $100^{\circ}\text{C}$ how long does one have to wait for the temperature to become $50^{\circ}\text{C}$.

7. During quenching, a cylindrical rod made of $1080\text{steel}$ ($k=43\text{W/m}.^{\circ}\text{C}$, $\rho=7801\text{ kg/m}^3$, $C=473\text{J/kg}.^{\circ}\text{C}$), $1\text{cm}$ diameter, and $20\text{cm}$ in length is first heated to $800^{\circ}\text{C}$ and then immersed in a water bath at $100^{\circ}\text{C}$. The heat transfer coefficient can be taken as $250\text{W/m}^2.^{\circ}\text{C}$. Calculate the time required for the rod to reach $250^{\circ}\text{C}$.

8. Consider a thermocouple junction, which may be approximated to a sphere, used for temperature measurement in a gas stream. The convection coefficient between the junction surface and the gas is $h=400\text{W/m}^2.\text{K}$, and the junction thermophysical properties are $k=20\text{W/m}.\text{K}$, $\rho=8500\text{ kg/m}^3$ and $C=400\text{J/kg}.\text{K}$. Determine the junction diameter needed for the thermocouple to have a time constant of $1\text{s}$. If the junction is at $25^{\circ}\text{C}$ and is placed in a gas stream that is at $200^{\circ}\text{C}$, how long will it take for the junction to reach $199^{\circ}\text{C}$?

9. It is required to determine the depth to which a change in surface temperature is felt during a 24hr period in underground water pipes. If the original soil temperature is $8^{\circ}\text{C}$ and the surface temperature suddenly drops to $-7^{\circ}\text{C}$, determine the depth upto which the freezing temperature penetrates. Assume that soil is dry and $\alpha=0.003\text{cm}^2/\text{s}$. 
10. A porcelain wall is 8mm thick with temperature 25°C. One of the walls is suddenly brought to 80°C and maintained thereafter. Estimate the point on the wall where the temperature is 40°C after a time of 2 seconds. $\alpha = 0.004\text{cm}^2/\text{s}$.

11. A thick concrete slab, initially at 400K, is sprayed with a large quantity of water at 300K. How long will the location, 5cm below the surface, take to cool to 320K?

12. A concrete wall, 20 cm thick, at an initial temperature of 20°C is suddenly exposed to pure steam at atmospheric pressure. If the thermal resistance of the condensate flowing down the wall is negligible, estimate the rate of steam condensation on 160m² wall area after (a) 10s (b) 3hrs.

13. Consider a 1.6 cm thick plate of carbon steel at the initial temperature $T_i = 600^\circ$C. This plate is plunged at $t = 0$ in a bath of water at a temperature $T_w = 15^\circ$C. The heat transfer coefficient is assumed constant and $h = 10^4 \text{ W/m}^2 \text{ K}$. Also, $k = 40 \text{ W/m K}$ and $\alpha = 0.1 \text{ cm}^2 / \text{ sec}$. Calculate the time $t$ when temperature in the mid plane of the steel plate drops to $T_e = 100^\circ$C. Determine also the corresponding temperature in a plane situated 0.2cm under one of the cooled surfaces. For a same time interval $t$, calculate the heat released by the plate as a fraction of total heat transfer that would be released in the limit $t \to \infty$.

14. A large aluminium plate 50 mm thick and initially at 200°C is suddenly exposed to the convective environment at 70°C. Calculate the temperature at a depth of 10 mm from one of the faces 1 minute after the plate has been exposed to the environment. Also find out the energy removed from the plate per unit area during this period. Take $C_p = 900 \text{ J/kg K}$, $k = 215 \text{ W/m K}$, $h = 500 \text{ W/m}^2 \text{ K}$, $\rho = 2700 \text{ kg/m}^3$, $\alpha = 8.5 \times 10^{-5}$ m²/s.

15. A two dimensional rectangular plate is subjected to the boundary conditions as shown. Derive an expression for steady state temperature distribution.