CONDUCTION TEST PROBLEMS

The non-proprietary test problems that have been used to validate one-dimensional heat conduction analysis in INSTED® are presented in this chapter. You might need to consult the original sources of the various test problems in order to assess the accuracy of INSTED® predictions. You will be expected to have simulated these sample problems before attempting to solve more realistic engineering problems. **The input data are contained in the distribution disks** under file names that are stated below in the discussion of each test problem.

Test Problem 1

☐ Problem Statement:

A furnace wall consists of a 1.2-cm-thick stainless steel inner layer covered by a 5-cm-thick outer layer of insulation. The temperature of the inside surface of the stainless steel is 800 K and the outside surface of the insulation is 350 K. Determine the heat-transfer rate through the furnace wall per unit area and the temperature of the interface between the stainless steel and the material of insulation. The thermal conductivities for steel and the asbestos are, respectively, k_1 = 19 W/m K, k_2 = 0.7 W/m K.

☐ Source:

Frank Kreith & William Z. Black. 1980. Basic Heat Transfer. Page 6. Harper & Row Publishers, New York.

☐ Comments

- This is a slab problem.
- Isothermal conditions apply at the two surfaces, no fins, no radiation.
- Note that area is 1 m^2 (per unit area).
- Data in the source are used.
- Diagnostic results from source are as follows:

Variable	**Kreith**	**INSTED®**	**Difference**
q (W)	6245.0	6244.75	<1%
Interface temperature, T_2	796.0	796.06	<1%

- Name of data file: Kreith.6

Test Problem 2

☐ Problem Statement:

A masonry wall of a building consists of an outer layer of facing brick (k = 1.32 W/m-°C) 10 cm thick, followed by a 15-cm-thick layer of common brick (k = 0.69 W/m-°C), followed by a 1.25-cm layer of gypsum plaster (k = 0.84 W/m-°C). An outside coefficient of 30 W/m-°C) may be expected, and a coefficient of 8 W/m^2-°C is a reasonable value to use for the inner surface of a ventilated room. What will be the rate of heat gain, per unit area, when the outside air is at 35°C and the inside air is conditioned to 22°C? What will be the temperature of the plastic?

☐ Source

Alan J. Chapman. 1987. Fundamentals of Heat Transfer. Macmillan Publishing Co. New York. Page 46.

Comments

- Data in source are used.
- Area is based on unity.
- Film coefficient is specified at the two surfaces; no fins, no radiation.
- Diagnostic results from source are as follows:

Variable	Chapman	INSTED®	Difference
q'' (W)	27.2	27.89	<3%
T_5 (°C)	24.4	25.47	< 1%

- Name of data file: chapman.46

Test Problem 3

Problem Statement:

A plastic (k = 0.5 W/mK) pipe carries a fluid such that the convective heat-transfer coefficient is 300 W/m^{2}K. The average fluid temperature is 100°C. The pipe has an inner diameter of 3 cm and an outer diameter of 4 cm. If the heat-transfer rate through the pipe per unit length is 500 *W*/m, calculate the external pipe temperature.

Source

Frank Kreith & William Z. Black. 1980. Basic heat transfer. Page 61. Harper & Row Publishers, New York.

Comments

- This is a radial conduction problem with 1 layer.
- Film coefficient on surface 1, isothermal conditions on surface 2, no radiation, no fins.
- The task is to calculate net temperature difference and the temperature at surface 2.
- Temperature at ambient of surface 2 is same as temperature at surface 2 (isothermal condition).
- Data in source are used.
- Unit length of pipe (already in meters) is considered.
- Heat flow rate is specified.
- Diagnostic result from source are as follows:

Variable	Kreith	INSTED®	Difference
ΔT (K)	63.5K	63.47	< 1%

- Name of data file: kreith.61

Test Problem 4

Problem Statement:

Calculate the heat loss per linear foot from a 3-in steel sched. 40 pipe (3.07 in. inner diameter, 3.500 in. outer diameter, k = 25 Btu/hr ft °F) covered with a 1/2- inch thickness of insulation (k = 0.11 Btu/ hr ft °F). The pipe transports a fluid at 300°F with an inner unit-surface conductance of

40 Btu/hr sq. ft °F and is exposed to ambient air at 80°F with an outer unit-surface conductance of 4.0 Btu/hr sq. ft °F.

Source:

Frank Kreith. 1973. Principles of heat transfer. Harper & Row Publishers. Page 43.

Comments

- This is a radial conduction problem with two layers.
- Film coefficient is to be specified on the two surfaces, no radiation, no fins.
- Data in source are used.
- Unit length of pipe is considered. That is, 1 foot.
- Diagnostic result from source:

Variable	**Kreith**	**INSTED®**	**Difference**
q''	362 Btu/hr ft (106.1 *W*/ft)	106.091 W/0.3048 m	< 1%

- Name of data file: Kreith73.43

Test Problem 5

Problem Statement:

(a) Heat is to be transferred through a plane wall, Δx = 1.25 cm thick, composed of a material with k = W/m-°C and the heat transfer coefficient there for all exposed surfaced is h = 450 W/m^2-°C. On the right side of the wall there is another ambient fluid at t = 20°C and the heat transfer coefficient there for all exposed surfaces is h = 25 W/m^2-°C. It is desired to enhance the heat transfer between the two fluids by using straight rectangular fins having a length L = 2.5 cm, thickness w = 0.16 cm, and spaced δ = 1.25 cm on centers, and a k the same as the wall. Assuming that a one-dimensional representation may be used, find the heat transfer between the two fluids, per unit of primary wall area, if fins are added to the right side only.

Source

Alan J. Chapman. 1987. Fundamentals of Heat Transfer. Macmillan Publishing Co. New York. Page 79.

Comments

- This is a slab conduction problem, with 1 layer.
- The system is finned on the right hand side. There is a fin coefficient on both surfaces; no radiation.
- Fin array analysis is performed to calculate the fin resistance that is needed for the conduction analysis. Single fin analysis must precede the analysis of the fin array. Automatic link with the fin analysis module is explored.
- The single fin plus the unfinned base area is considered a fin array! Fin width is 1 m.

- Normal area of conduction region is 0.0125 x 1 m^2.
- Total surface area of fin is 0.0516 at surface 2.
- Total area at surface 2 (including fin) is 0.0625
- Calculations are done in SI in INSTED.
- Data in source are used.
- Diagnostic results from source are as follows:

Variable	**Chapman**	**INSTED®**	**Difference**
q'' (W/m^2) -(a)	2364.9	2364.92	<1%
q'' (W/m^2) - (b)	9526.*6*	9628.30	<2%
Fin Resist. -(b) (m^{2}K/W)	0.008211	0.0081013	<2%

♦ Name of data file: Chapman.79a (conduction), Chapman.79b (fin analysis subtask).

Test Problem 6

☐ **Problem Statement:**

Calculate the rate of heat loss from a furnace wall per unit area. The wall is constructed from an inner layer of 0.5-cm-thick steel (k=40 W/m K) and an outer layer of 10-cm zirconium brick (k=2.5 W/m K). The inner-surface temperature is 900K and the outside surface temperature is 460K. What is the temperature at the interface?

☐ **Source**

Frank Kreith & Mark S. Bohn, 1993. Fifth Edition. Principles of heat transfer. West Education Publishing, Boston. Page 17

☐ **Comments**

- This is a slab conduction problem, with 1 layer.

Variable	**Chapman**	**INSTED®**	**Difference**
Interface Temp (K)	898.60	898.63	
q'' (W) for *1* m^2	10965.0	10965.7	<1%

♦ Name of data file: Krbohn.027