FIN TEST PROBLEMS

The non-proprietary test problems that have been used to validate fin analysis in INSTED® are discussed in this section. You might need to consult the original sources of the various test problems in order to assess the accuracy of INSTED® predictions in more detail. These sources are given, as are a few notes to aid in the comparison exercise. Some diagnostic results reported in the sources are presented here and compared with 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:**

To increase the heat dissipation from a 2.5-cm-outer diameter tube, circumferential fins made of aluminum (k = 200 W/m K) are soldered to the outer surface. The fins are 0.1 cm thick and have an outer diameter of 5.5 cm as shown in Figure 2.20 (of source). If the tube temperature is 100°C, the environmental temperature is 25°C, and the heat transfer coefficient between the fin and environment is 65 W/m^{2}K, calculate the rate of heat loss from a fin.

- **Source:**

Frank Kreith & Mark S. Bohn. 1993. Fifth Edition. Principles of heat transfer. West Educational Publishing, Boston. Page 107.

- **Comments:**
  - Select "Approximate Analysis"
  - Diagnostic results from source areas are as follows:

Variable	**Kreith**	**INSTED®**	**Difference**
q (W)	17.5	17.33	<1%
η	.91	.901	<1%

Name of data file: Krbohn.107

Test Problem 2

- **Problem Statement:**

Determine the heat transfer rate from a rectangular fin of the type in the Figure on page 83 of the source. The tip of the fin is not insulated and the fin has a thermal conductivity of 150 W/mK. The base temperature is 100°C and the fluid is at 20°C. The heat transfer coefficient between the fin and fluid is 30 W/m^{2}K.

- **Source:**
  Frank Kreith & William Z. Black. 1980. Basic Heat Transfer. Page 82-83. Harper & Row Publishers, New York.

- **Comments:**
  - Fin length is 20 cm, thickness is 2 cm, and width is 40 cm.
  - SI units are used in INSTED. Make use of online unit conversion in INSTED to convert from °C to K when specifying temperatures.
  - Data in source are used.
  - Diagnostic results from source:

Variable	**Kreith**	**INSTED®**	**Difference**
Q (W)	327	316.26	<4%
η	.775	.7844	<2%

  - Explanation of difference in solution between source and INSTED: Interpolation from efficiency curve, rounding- off in source.

Name of data file: Kreith.82

Test Problem 3

- **Problem Statement:**
  An aluminum (k = 200 W/mK) annular fin is placed on a copper tube that carries a fluid. The tube is 8 cm o.d. The fluid is at 25°C. The fin is 0.5 cm thick and 16 cm o.d. The surrounding fluid is at 70°C and the convective heat transfer coefficient is 60 W/m K. Determine the heat transfer rate from the fin.
- **Source:**
  Frank Kreith & William Z. Black. 1980. Basic Heat Transfer. Page 83-84. Harper & Row Publishers, New York.
- **Comments:**
  - Data in source are used.
  - Diagnostic results from source:

Variable	**Kreith**	**INSTED®**	**Difference**
Q (W)	314	310.39	<2%
η	.89	.8786	<2%

  - Explanation of difference: Interpolation from efficiency curve, rounding-off in source.
  - Name of data file: Kreith.83

Test Problem 4

- **Problem Statement:**
  The cylinder barrel of a motorcycle is constructed of 2024-T6 aluminum alloy and is of height h = 0.15 m and an outside diameter of D = 50 mm. Under typical operating conditions, the outer surface of the cylinder is at a temperature of 500K and is exposed to ambient air at 300 K, with a convection coefficient of 50 W/m^2K. Annular fins of rectangular profile are typically added to increase heat transfer to the surroundings. Assume that five such fins, which are of thickness t = 6 mm, length L = 20 mm and equally spaced are added. What is the increase in heat transfer due to the addition of the fins?

- **Source:**
  Frank P. Incropera & David P. Dewitt. 1990. Introduction to heat transfer. Second edition, John Wiley & Sons, New York. Page 135.
- **Comments:**
  - This is a problem on fin arrays. Fin type is annular fin of rectangular cross section.
  - Data in source are used.
  - Only the case with fins is analyzed with INSTED. The conduction module will be more appropriate for the simpler case of conduction without fins.
  - k = 186 W/ mK.

  Diagnostic results from the source are as follows:

Variable	**Incropera**	**INSTED®**	**Difference**
Q (W), array	690	688.39	<1%
η, single fin	0.95	0.9477	<1%
$L_c^{3/2} (h/KA)^{1/2}$	0.15	0.15395	2%
Overall surface efficiency	0.963	0.9614	<1%

  - Name of data file: INCROP.135

Test Problem 5

- **Problem Statement:**
  A fin is to be made of an aluminum alloy (k = 64 Btu/h-ft-°F) and is to be used to enhance the heat transfer between a primary surface and an ambient fluid where the surface heat transfer coefficient is 52 Btu/ $h\text{-}ft^2$-°F). Different fin shapes are to be considered, but let the fin thickness at the base be 0.05 in. in every case. Find the efficiency of the fin if:
  a) a straight fin of rectangular profile with a length of 1.0 in.
  b) a straight fin of triangular profile with a length of 1.0 in.

c) an annular fin of rectangular profile with a base radius of 1.0 in. and an end radius of 2.0 in.

If the fins have a base temperature of 200°F and transfer heat with an ambient fluid of 80°F, find the rate of heat transfer. In the case of straight fins, find the heat flow per unit width of fin.

- **Source:**

Alan P. Chapman. 1987. Fundamentals of heat transfer. Macmillan Publishing Company, New York. Page 75-77.

- **Comments:**
  - Data in source are used.
  - Note that per unit length of width in the problem statement implies per 1 foot. It is important that you go through unit conversion to specify a width in meters, which is equivalent to 1 foot.
  - As is evident from above, the heat flow rate results in INSTED predictions will be based on 1 foot. Further unit conversion is needed to calculate power per unit meter. These comments apply only to the straight fins where a width is defined.

  - Diagnostic results from source for "Chapman.75(a)" are as follows:

Variable	**Chapman**	**INSTED®**	**Difference**
q' (W/m)	574.30	574.349	< 1%
η	.5641	0.560389	< 1%

  - Diagnostic results from source for "Chapman.75(b)" are as follows:

Variable	**Chapman**	**INSTED®**	**Difference**
q' (W/m)	504	504.103	< 1%
η	.50	0.503989	< 1%

  - Diagnostic results from source for "Chapman.75(c)" are as follows:

Variable	**Chapman**	**INSTED®**	**Difference**
q' (W/m)	114.6	114.606	< 1%
η	.480	0.463248	< 4%

a) Names of data files: Chapman.75a, Chapman.75b, Chapman.75c

Test Problem 6

- **Problem Statement:**

A long rod 25 mm in diameter has one end maintained at 100°C. The surface of the rod is exposed to ambient air at 25°C with a convective heat transfer coefficient of 10 W/m^2K. What are the heat losses from rods constructed of pure copper and type AISI 316 stainless steel.

- **Source:**

Frank P. Incropera & David Dewitt. 1990. Introduction to heat transfer. Second edition. John Wiley & Sons, New York. Page 128.

- **Comments:**
  - Use "Detailed Analysis", Cylindrical (Circular) Fin.
  - SI units are used in INSTED. Use online unit conversion as needed.
  - Data in source are used.
  - *k*= 398 W/mK for copper. *k*= 14 W/mK for stainless steel.
  - The requirement of infinite length of fin implies the use of the Detailed (exact) approach, which allows imposition of various boundary conditions.
  - Only the case for copper is calculated. You can substitute thermal conductivity of steel to obtain the results for steel.
  - Diagnostic results from the source for copper are as follows:

Variable	**Incropera**	**INSTED®**	**Difference**
q (W)	29.4	29.5	<1%

  - Name of data file: Incrop.128

Test Problem 7

- **Problem Statement:**

An experimental device that produces excess heat is passively cooled. The addition of pin fins to the casing of this device is being considered to augment the rate of cooling. Consider a copper pin fin 0.25 cm in diameter that protrudes from a wall at 95°C into ambient air at 25°C as shown in Fig. 21.16 (of source). The heat transfer is mainly by natural convection with a coefficient equal to 10 W/m^2 K. Calculate the heat loss, assuming that (a) the fin is "infinitely long" and (b) the fin 2.5 m long and the coefficient at the end is the same as around the circumference.

- **Source:**

Frank Kreith & Mark S. Bohn. 1993. Fifth Edition. Principles of heat transfer. West Educational Publishing, Boston. Page 103.

- **Comments:**
  - Select "Detailed Analysis"
  - Diagnostic results from source areas are as follows:

Variable	**Kreith**	**INSTED®**	**Difference**
q (W) -(a)	0.865	0.8649	<1%
q (W) -(b)	0.140	0.1396	<1%

Name of data file: Krbohn.103