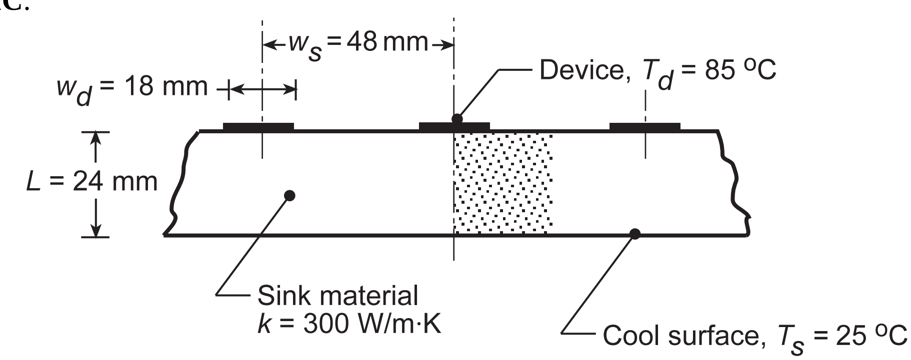
PROBLEM 4.93

KNOWN: Electronic device cooled by conduction to a heat sink.

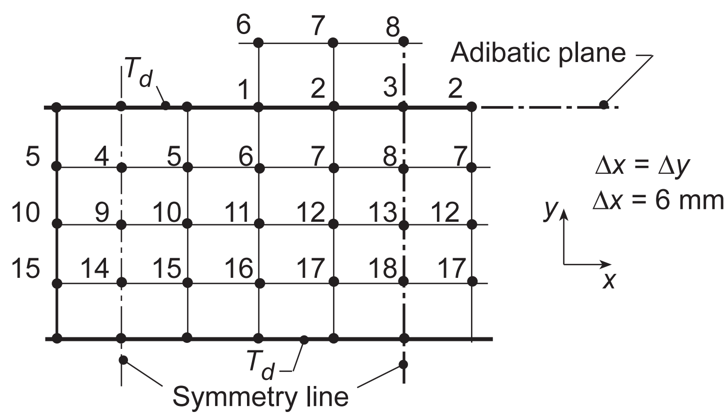
FIND: (a) Beginning with a symmetrical element, find the thermal resistance per unit depth between the device and lower surface of the sink, $R'_{t,d-s}$ (m·K/W) using a coarse (5x5) nodal network, determine $R'_{t,d-s}$; (b) Using nodal networks with finer grid spacings, determine the effect of grid size on the precision of the thermal resistance calculation; (c) Using a fine nodal network, determine the effect of device width on $R'_{t,d-s}$ with w_d/w_s = 0.175, 0.275, 0.375 and 0.475 keeping w_s and L fixed.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, two-dimensional conduction, (2) Constant properties, and (3) No internal generation, (4) Top surface not covered by device is insulated.

ANALYSIS: (a) The coarse 5x5 nodal network is shown in the sketch including the nodes adjacent to the symmetry lines and the adiabatic surface. As such, all the finite-difference equations are interior nodes and can be written by inspection directly onto the IHT workspace. Alternatively, one could use the *IHT Finite-Difference Equations Tool*. The temperature distribution (°C) is tabulated in the same arrangement as the nodal network.



85.00	85.00	62.31	53.26	50.73
65.76	63.85	55.49	50.00	48.20
50.32	49.17	45.80	43.06	42.07
37.18	36.70	35.47	34.37	33.95
25.00	25.00	25.00	25.00	25.00

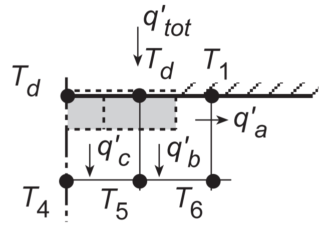
The thermal resistance between the device and sink per unit depth is

$$R'_{t,s-d} = \frac{T_d - T_s}{2q'_{tot}}$$

Continued…

PROBLEM 4.93 (Cont.)

Performing an energy balance on the device nodes, find



$$q'_{tot} = q'_a + q'_b + q'_c$$

$$q'_{tot} = k\left(\Delta y/2\right)\frac{T_d - T_1}{\Delta x} + k\Delta x\frac{T_d - T_5}{\Delta y} + k\left(\Delta x/2\right)\frac{T_d - T_4}{\Delta y}$$

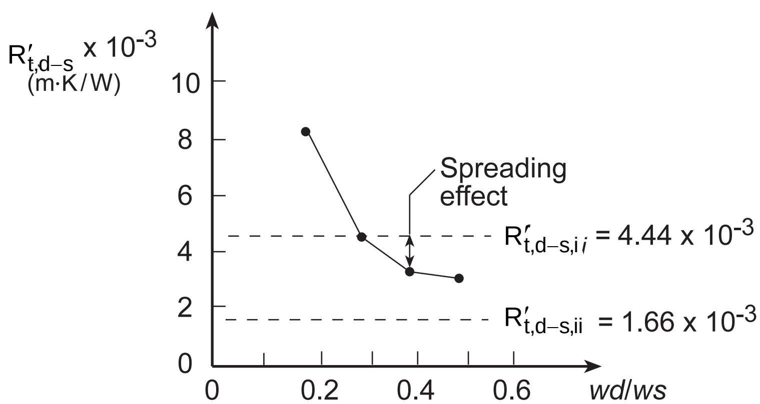
$$q'_{tot} = 300\,\mathrm{W/m\cdot K}\left[\left(85-62.31\right)/2 + \left(85-63.85\right) + \left(85-65.76\right)/2\right]\mathrm{K} = 1.263\times10^{4}\ \mathrm{W/m}$$

$$R'_{t,s-d} = \frac{\left(85-25\right)\mathrm{K}}{2\times1.263\times10^{4}\ \mathrm{W/m}} = 2.38\times10^{-3}\,\mathrm{m\cdot K/W}$$ <

(b) The effect of grid size on the precision of the thermal resistance estimate should be tested by systematically reducing the nodal spacing Δx and Δy. This is a considerable amount of work even with IHT since the equations need to be individually entered. A more generalized, powerful code would be required which allows for automatically selecting the grid size. Using FEHT, a finite-element package, with eight elements across the device, representing a much finer mesh, we found

$$R'_{t,s-d} = 3.64\times10^{-3}\ \mathrm{m\cdot K/W}$$

(c) Using the same tool, with the finest mesh, the thermal resistance was found as a function of w_d/w_s with fixed w_s and L.



As expected, as w_d increases, $R'_{t,d-s}$ decreases, and eventually will approach the value for the rectangular domain (ii). The spreading effect is shown for the base case, w_d/w_s = 0.375, where the thermal resistance of the sink is less than that for the rectangular domain (i).

COMMENTS: It is useful to compare the results for estimating the thermal resistance in terms of precision requirements and level of effort,

	$R'_{t,d-s} \times 10^3$ (m·K/W)
Rectangular domain (i)	4.44
Flux plot	3.03
Rectangular domain (ii)	1.67
FDE, 5x5 network	2.38
FEA, fine mesh	3.64