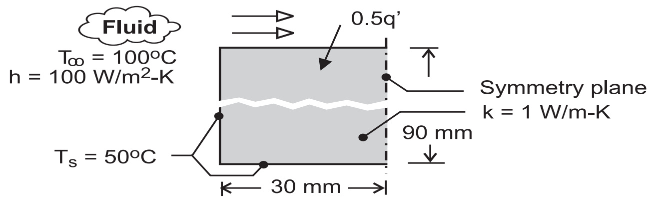
PROBLEM 4.88

KNOWN: Long rectangular bar having one boundary exposed to a convection process (T_∞, h) while the other boundaries are maintained at constant temperature T_s.

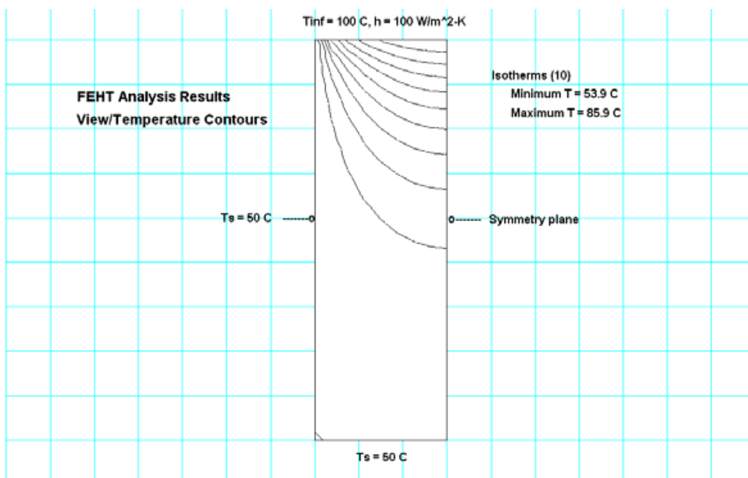
FIND: Using the finite-element method of FEHT, (a) Determine the temperature distribution, plot the isotherms, and identify significant features of the distribution, (b) Calculate the heat rate per unit length (W/m) into the bar from the air stream, and (c) Explore the effect on the heat rate of increasing the convection coefficient by factors of two and three; explain why the change in the heat rate is not proportional to the change in the convection coefficient.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, two dimensional conduction, (2) Constant properties.

ANALYSIS: (a) The symmetrical section shown in the schematic is drawn in FEHT with the specified boundary conditions and material property. The *View* | *Temperature Contours* command is used to represent ten isotherms (isopotentials) that have minimum and maximum values of 53.9°C and 85.9°C, respectively.



Because of the symmetry boundary condition, the isotherms are normal to the center-plane indicating an adiabatic surface. Note that the temperature change along the upper surface of the bar is substantial (≈ 40°C), whereas the lower half of the bar has less than a 3°C change. That is, the lower half of the bar is largely unaffected by the heat transfer conditions at the upper surface.

(b, c) Using the *View* | *Heat Flows* command considering the upper surface boundary with selected convection coefficients, the heat rates into the bar from the air stream were calculated.

$h\left(W/m^2\cdot K\right)$	100	200	300
$q'(W/m)$	128	175	206

Increasing the convection coefficient by factors of 2 and 3, increases the heat rate by 37% and 61%, respectively. The heat rate from the bar to the air stream is controlled by the thermal resistances of the bar (conduction) and the convection process. Since the conduction resistance is significant, we should not expect the heat rate to change proportionally to the change in convection resistance.