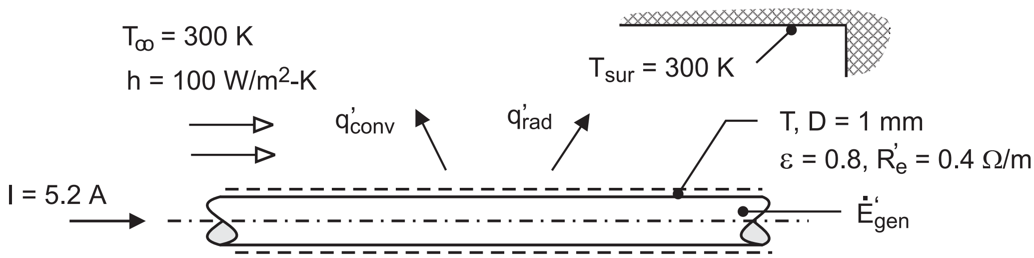
PROBLEM 1.60

KNOWN: Rod of prescribed diameter experiencing electrical dissipation from passage of electrical current and convection under different air velocity conditions. See Example 1.4.

FIND: Rod temperature as a function of the electrical current for $0 \le I \le 10$ A with convection coefficients of 50, 100 and 250 $W/m^2 \cdot K$. Will variations in the surface emissivity have a significant effect on the rod temperature?

SCHEMATIC:



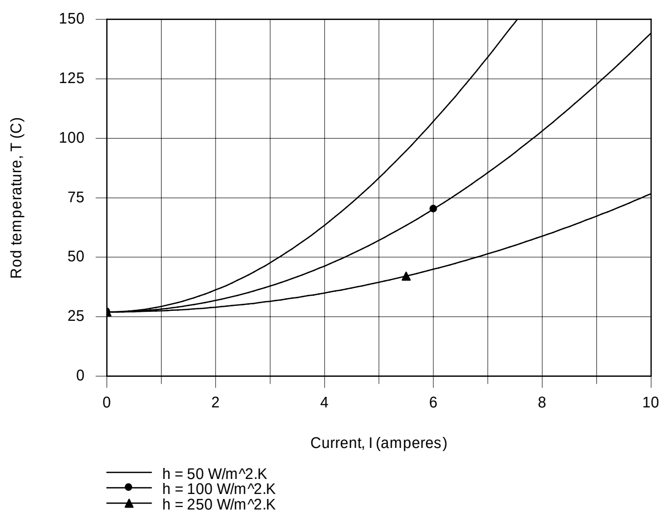
ASSUMPTIONS: (1) Steady-state conditions, (2) Uniform rod temperature, (3) Radiation exchange between the outer surface of the rod and the surroundings is between a small surface and large enclosure.

ANALYSIS: The energy balance on the rod for steady-state conditions has the form,

$$q'_{conv} + q'_{rad} = \dot{E}'_{gen}$$

$$\pi D h \left(T - T_\infty\right) + \pi D \varepsilon \sigma \left(T^4 - T_{sur}^4\right) = I^2 R'_e$$

Using this equation in the Workspace of IHT, the rod temperature is calculated and plotted as a function of current for selected convection coefficients.



COMMENTS: (1) For forced convection over the cylinder, the convection heat transfer coefficient is dependent upon air velocity approximately as $h \sim V^{0.6}$. Hence, to achieve a 5-fold change in the convection coefficient (from 50 to 250 $W/m^2 \cdot K$), the air velocity must be changed by a factor of nearly 15.

Continued …..

PROBLEM 1.60 (Cont.)

(2) For the condition of I = 4 A with h = 50 W/m^2·K with T = 63.5°C, the convection and radiation exchange rates per unit length are, respectively, $q'_{conv} = 5.7\ W/m$ and $q'_{rad} = 0.67\ W/m$. We conclude that convection is the dominant heat transfer mode and that changes in surface emissivity could have only a minor effect. Will this also be the case if h = 100 or 250 W/m^2·K?

(3) What would happen to the rod temperature if there was a "loss of coolant" condition where the air flow would cease?

(4) The Workspace for the IHT program to calculate the heat losses and perform the parametric analysis to generate the graph is shown below. It is good practice to provide commentary with the code making your solution logic clear, and to summarize the results. It is also good practice to show plots in *customary* units, that is, the units used to prescribe the problem. As such the graph of the rod temperature is shown above with Celsius units, even though the calculations require temperatures in kelvins.

```
// Energy balance; from Ex. 1.4, Comment 1
-q'cv - q'rad + Edot'g = 0
q'cv = pi*D*h*(T - Tinf)
q'rad = pi*D*eps*sigma*(T^4 - Tsur^4)
sigma = 5.67e-8

// The generation term has the form
Edot'g = I^2*R'e
qdot = I^2*R'e / (pi*D^2/4)

// Input parameters
D = 0.001
Tsur = 300
T_C = T – 273          // Representing temperature in Celsius units using _C subscript
eps = 0.8
Tinf = 300
h = 100
//h = 50               // Values of coefficient for parameter study
//h = 250
I = 5.2                // For graph, sweep over range from 0 to 10 A
//I = 4                // For evaluation of heat rates with h = 50 W/m^2.K
R'e = 0.4

/*  Base case results: I = 5.2 A with h = 100 W/m^2.K, find T = 60 C (Comment 2 case).
Edot'g      T       T_C     q'cv    q'rad   qdot            D       I       R'e
            Tinf    Tsur    eps     h       sigma
10.82       332.6   59.55   10.23   0.5886  1.377E7         0.001   5.2     0.4
            300     300     0.8     100     5.67E-8   */

/* Results: I = 4 A with h = 50 W/m^2.K, find q'cv =  5.7 W/m and q'rad = 0.67 W/m
Edot'g      T       T_C     q'cv    q'rad   qdot    D       I       R'e
      Tinf  Tsur    eps     h       sigma
6.4         336.5   63.47   5.728   0.6721  8.149E6 0.001   4       0.4
      300   300     0.8     50      5.67E-8    */
```