GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2000

Heat Transfer
EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

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Ph.D. Qualifying Exam

Heat Transfer

1. A long, cylindrical copper conductor, 2.5 cm in diameter $(k_{cu} = 390 W/m \cdot K)$ is covered with a 1-cm thick layer of phenolic insulation $(k_I = 0.03 W/m \cdot C)$. The estimated internal heat generation in the conductor is 39 kW/m^3, the surface heat transfer coefficient is $h = 32$ W/m^2-^oC. and the outside environment temperature is 30°C.

   a. Develop algebraic expressions for the outside and inside surface temperatures of the phenolic insulation. Calculate these values.

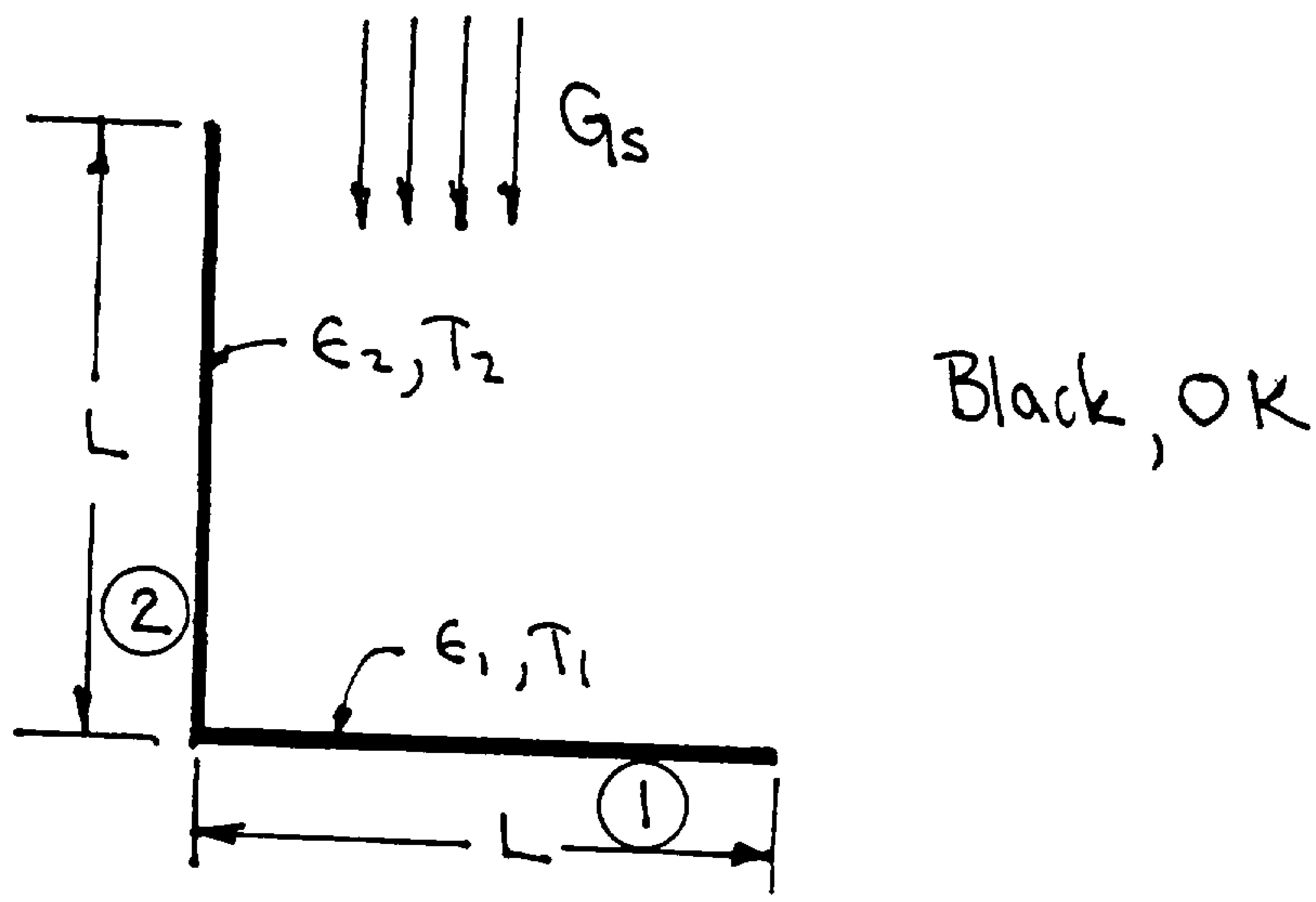
   b. Draw a qualitative sketch showing the temperature distributions inside the conductor, in the phenolic insulation and in the outside air film. Do you expect the temperature distribution in the insulation material to be linear? Explain your response.

   c. Write the governing differential equations and applicable boundary conditions that should be used to determine the temperature distributions in the conductor and in the phenolic insulation.

   d. "Burn out" occurs in electric conductors and electric coils if the temperature of the metal reaches the melting point. Set forth the mathematical criteria leading to this situation for the problem described above.

2. Two gray, diffuse, isothermal, opaque surfaces are placed in outer space (black at 0K) and solar irradiation G_s is incident on surface 1 as shown in the figure. The surfaces are very long into the figure and they are insulated on the back surfaces. The emissivities of the two surfaces are ε_1 and ε_2 and they have known temperatures T_1 and T_2.

Determine sufficient expressions that you could use to determine the net radiative flux for both surfaces 1 and 2. Your answer may be left in terms of the symbols shown in the figure. You do not need to solve the equations for q_{1net} and q_{2net}, only derive them.



3. Use a control volume energy balance to derive the energy integral relation for a two-dimensional boundary layer

$$\int_0^x q''_w dx = \rho c \int_0^\Delta u(T - T_\infty) dy = -k \int_0^x \left(\frac{\partial T}{\partial y}\right)_{y=0} dx$$

Δ is the thermal boundary layer thickness, T_∞ is the free stream fluid temperature and q''_w is the wall heat flux. Assume that viscous dissipation is negligible.

For a uniform fluid velocity within the boundary layer $(u = U_\infty)$ and an assumed linear temperature profile in the boundary layer

$$\frac{T - T_\infty}{T_w - T_\infty} = 1 - \frac{y}{\Delta}$$

show that the local Nusselt number is

$$Nu_x = \frac{x}{\Delta} = \frac{\sqrt{2}}{2} Pe_x^{1/2}$$