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Heat Transfer (Exam II)

1- (40%) A common annoyance in cars in winter months is the formation of fog on the glass surfaces that blocks the view. A practical way of solving this problem is to blow hot air or to attach electric resistance heaters to the inner surfaces. Consider the rear window of a car that consists of a 0.4-cm-thick glass (k = 0.84 W/m°C and α = 0.39 m^2/s). Strip heater wires of negligible thickness are attached to the inner surface of the glass, 4 cm apart. Each wire generates heat at a rate of 25 W/m length. Initially the entire car, including its windows, is at the outdoor temperature of T_o = - 3 °C. The heat transfer coefficients at the inner and outer surfaces of the glass can be taken to be h_i = 6 and h_o = 20 W/m^2 °C, respectively. Using the explicit finite difference method with a mesh size of Δx = 0.2 cm along the thickness and Δy = 1 cm in the direction normal to the heat wires, determine the following:

a) Draw the mesh of the grid by showing the total number of unknown nodes. (Note you should recognize the symmetry to minimize the total number of unknown nodes).

b) Using the explicit scheme write the energy equation for the element that contains the electric wire heating element.

c) For this particular element "part b" find the required time step for its stability.

2- (30%) The water main in the cities must be placed at sufficient depths below the earth's surface to avoid freezing during periods of subfreezing temperatures. Determine the minimum depth at which the water main must be placed at a location where the soil is initially at 15 °C and the earth's surface temperature under the worst conditions is expected to reach a temperature of -10 °C for a period of 75 days. Take the properties of soil at that location to be k = 0.7 W/m°C and $\alpha = 1.4 \times 10^{-5}$ m^2/s. (Make sure that at the selected depth, the freezing does not occur over the period of 75 days)

3- (30%) The roof of a house consists of a 15-cm-thick concrete slab (k = 0.7 W/m°C) that is 15 m wide and 20 m long. The convection heat transfer coefficient on the inner surface of the roof is 5 W/m^2 °C. On a clear winter night, the ambient air is reported to

be at 10 °C, while the night sky temperature is 100 °K. The house and the interior surfaces of the wall are maintained at a constant temperature of 20 °C. The emissivity of both surfaces of the concrete roof is 0.9. Considering both radiation and convection heat transfer, and the outdoor wind at 60 km/h (over the 20-m long side) blowing over the roof. Determine the following:

a) The outdoor convective heat transfer coefficient.
b) Draw the thermal resistance circuit for the roof
c) The rate of heat transfer through the roof