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This is a blank page for you to write down your answer to problem 1(a).

$$R_{equiv} = (hL^2 + R_t^{-1})^{-1}$$

$$\rho (L^2 \cdot d) \cdot c_p \frac{dT}{dt} = \dot{q} (L^2 \cdot d) - \frac{T - T_\infty}{R_{equiv}}$$

$$\theta \equiv \frac{T - T_\infty}{R_{equiv}} - \dot{q} L^2 d$$

$$\rho (L^2 d) c_p R_{equiv} \frac{d\theta}{dt} = -\theta$$

$$t = -\rho L^2 d \cdot c_p R_{equiv} \ln \left[\frac{\dot{q} L^2 d - \frac{T - T_\infty}{R_{equiv}}}{\dot{q} L^2 d} \right]$$

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(b) (5 points)
Assume $L = 5mm$, $d = 1mm$, $h = 150W/m^2 \cdot K$, $T_\infty = 20^0C$, $R_t = 200K/W$, $\rho = 2000kg/m^3$, $c_p = 700J/kg \cdot K$, $\dot{q} = 9 \times 10^6 W/m^3$. Following activation of the chip, how long does it take to come within 1^0C of the new steady-state temperature?

$$\frac{T_{steady} - T_\infty}{R_{equiv}} = \dot{q} L^2 d.$$

$$T_{steady} = T_\infty + R_{equiv} \dot{q} L^2 d = 45.7^\circ C$$

$$T = 44.7^\circ C.$$

$$t = -2000 (5\times10^{-3})^2 \times 1\times10^{-3} \times 700 \times 114.3$$

$$\ln\left[\frac{9\times10^6 \times (5\times10^{-3})^2 \times 1\times10^{-3} - \dfrac{44.7-20}{114.3}}{9\times10^6 \times (5\times10^{-3})^2 \times 1\times10^{-3}}\right]$$

$$= 12.9\ s$$

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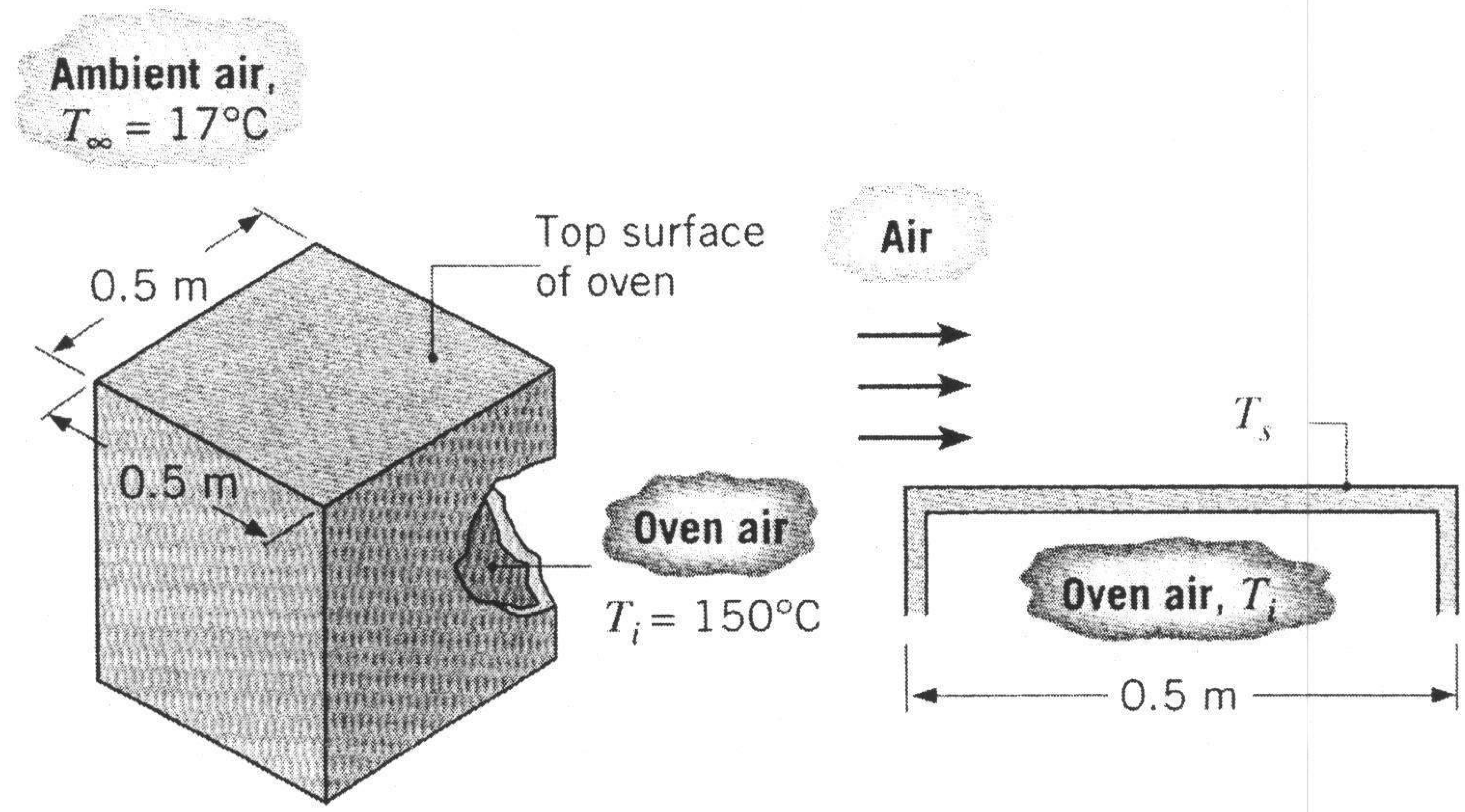
Problem 2 (15 points)
Initially the top surface of an oven measuring $0.5m$ by $0.5m$ is at a uniform temperature of $47^0 C$ under stationary room air conditions. The inside air temperature of the oven is $150^0 C$, the room air temperature is $17^0 C$, and the heat transfer from the surface is $40W$. Assume constant material properties of air: thermal conductivity $k = 0.0263 \mathrm{W/m \cdot K}$, kinematic viscosity $\nu = 15.89 \times 10^{-6} m^2/s$, $\mathrm{Pr} = 0.707$. Neglect radiation.



(a) (8 points)
In order to reduce the surface temperature and meet safety requirements, room air is blown across the top surface with a velocity of $20m/s$ in a direction parallel to an edge. Assume that the temperature of the top surface is still uniform. What is the average heat transfer coefficient for the top surface?

$$Re_L = \frac{u_\infty \cdot L}{\nu} = 6.293 \times 10^5$$

$$\overline{Nu}_L = (0.037 Re_L^{4/5} - 871) Pr^{1/3} = 660.0.$$

$$\bar{h}_L = \frac{\overline{Nu}_L \cdot k}{L} = 34.7 \ W/m^2 \cdot K.$$

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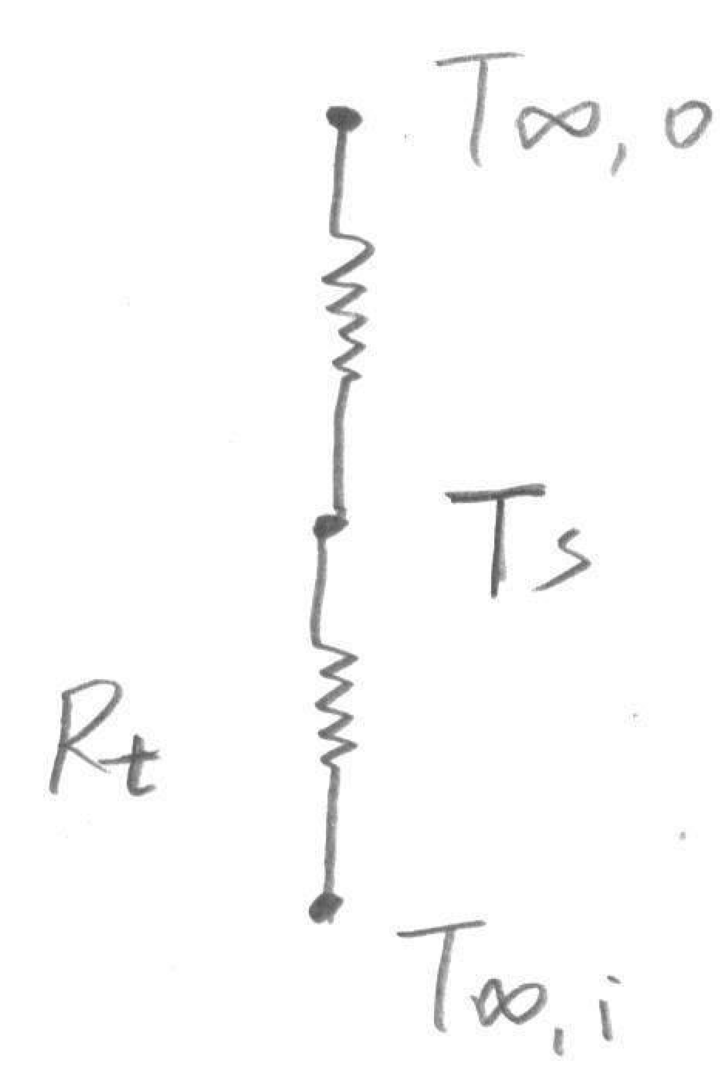
(b) (7 points)
Assume that internal convection conditions and the thermal resistance due to the oven wall remain unchanged no matter whether the room air is stationary or is blown across the top surface. Estimate the top surface temperature when the room air is blown across the top surface with a velocity of $20 m/s$ in a direction parallel to an edge.

$$R_t = \frac{T_i - T_{s,\,stationary}}{q} = \frac{150 - 47}{40}$$

$$= 2.575\ K/W$$



$$(T_s - T_{\infty,o})\, \bar{h}_L \cdot L^2 = \frac{T_{\infty,i} - T_s}{R_t}$$

$$T_s = \frac{\bar{h}_L \cdot L^2\, T_{\infty,o} R_t + T_{\infty,i}}{1 + R_t \cdot \bar{h}_L L^2}$$

$$= \frac{34.7 \times 0.5^2 \times 17 \times 2.575 + 150}{1 + 2.575 \times 34.7 \times 0.5^2}$$

$$= 22.7\ ^\circ C$$