Given

- Plate size: $W = 0.36\,\text{m}$ (width), $L = 0.36\,\text{m}$ (length along flow)
- Upstream unheated length: $\xi = L/2 = 0.18\,\text{m}$
- Downstream heated length: $L_h = L - \xi = 0.18\,\text{m}$
- Free-stream air: $U = 4.0\,\text{m/s}$, $T_\infty = 35\,^\circ\text{C}$
- Heat input: $Q = 40\,\text{W}$
- Air properties at the film temperature (assuming the base reaches 119°C and the ambient is 35°C, so $T_f = \frac{119+35}{2} = 77°\text{C} \approx 350$ K):

$$k = 0.03\,\text{W/m}\cdot\text{K}, \quad \nu = 20.92 \times 10^{-6}\,\text{m}^2/\text{s}, \quad Pr = 0.7$$

1) Reynolds Number and Flow Regime

$$Re_L = \frac{UL}{\nu} = \frac{(4.0)(0.36)}{20.92 \times 10^{-6}} = 6.88 \times 10^4$$

Since $Re_L < 5 \times 10^5$, the flow is **laminar**.

2) Average Nusselt Numbers

Plate with unheated start length

$$\overline{Nu}_L = (\overline{Nu}_L)_{\xi=0} \frac{L}{L-\xi} \left[1 - \left(\frac{\xi}{L}\right)^{\frac{p+1}{p+2}}\right]^{\frac{p}{p+1}}$$

where $(\overline{Nu}_L)_{\xi=0}$ is the average Nusselt number for a flat plate heated from the leading edge. For laminar flow, it is obtained from

$$\overline{Nu}_x = \frac{\bar{h}_x x}{k} = 0.664\, Re_x^{1/2}\, Pr^{1/3}, \qquad Pr \gtrsim 0.6$$

Substituting the values:

$$(\overline{Nu}_L)_{\xi=0} = 0.664 \times (6.88 \times 10^4)^{1/2} \times (0.7)^{1/3} \approx 154.7$$

For laminar flow $p = 2$ and for turbulent flow $p = 8$:

$$\frac{L}{L-\xi} = \frac{0.36}{0.18} = 2$$

$$\left(\frac{\xi}{L}\right)^{\frac{p+1}{p+2}} = 0.5^{3/4} \approx 0.595, \quad 1 - 0.595 = 0.405, \quad (0.405)^{2/3} \approx 0.547$$

$$\Rightarrow \overline{Nu}_L = (154.7)(2)(0.547) \approx 169.2$$

3) Convection Coefficient

$$\bar{h} = \frac{k\,\overline{Nu}_L}{L}$$

$$\bar{h} = \frac{0.03 \times 169.2}{0.36} = 14.1\,\mathrm{W/m^2{\cdot}K}$$

4) Average Surface Temperature

$$T_s = T_\infty + \frac{Q}{\bar{h}A}$$

$$A_{\mathrm{hot}} = WL_h = (0.36)(0.18) = 0.0648\ \mathrm{m}^2$$

$$T_s = 35 + \frac{40}{14.1 \times 0.0648} = 35 + 43.78 = \mathbf{78.78^\circ C}$$