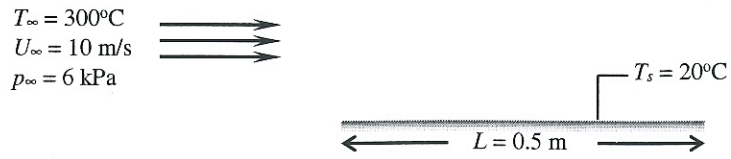
Example

Air at a pressure of 6 kPa and a temperature of 300°C flows with a velocity of 10 m/s over a plate of length 0.5 m. Estimate the cooling rate per unit width of the plate needed to maintain it at a surface temperature of 20°C.



- PROPERTIES $T_f = \frac{T_s + T_\infty}{2} = \frac{(20 + 300)°C}{2} = 160°C = 433\ K$

TABLE LOOK UP $\Rightarrow$ $k = 0.03511\ W/m\cdot K$, $\mu = 2.420 \times 10^{-5}\ kg/m\cdot s$, $Pr = 0.701$

DO NOT USE ρ IN TABLE!

$P_\infty \neq P_{ATM}$

USE IDEAL GAS

$\rho = P/RT = \frac{6\ kPa}{(0.287\ \frac{kJ}{kg\cdot K})(433\ K)}$

$= 0.0483\ kg/m^3$

- REYNOLD'S NUMBER

$Re = \frac{\rho U_\infty L}{\mu}$

$= \frac{(0.0483\ \frac{kg}{m^3})(10\ \frac{m}{s})(0.5\ m)}{2.420 \times 10^{-5}\ \frac{kg}{m\cdot s}} = 9976$ $\rightarrow$ LAMINAR OVER WHOLE PLATE

- BC IS $T_S = CONST$

- LAMINAR
- FLAT PLATE
- $T_S = CONST$
- WANT AVERAGE (NOT LOCAL) h

$\Rightarrow$ $Nu = 0.664\ Re^{1/2}\ Pr^{1/3}$

$= (0.664)(9976)^{1/2}(0.701)^{1/3}$

$= 58.9$

$Nu = \frac{hL}{k_{Fluid}}$ $\quad h = \frac{Nu \cdot k_{Fluid}}{L} = \frac{(58.9)(0.03511\ \frac{W}{m\cdot C})}{0.5\ m} = 4.14\ \frac{W}{m^2 \cdot °C}$

$$\dot{Q} = hA(T_\infty - T_s)$$

$$= h(L \times 1m)(T_\infty - T_s)$$

$$= \left(4.14 \frac{W}{m^2 \cdot °C}\right)(0.5\,m)(1\,m)(300°C - 27°C)$$

$$= \boxed{579\,W}$$