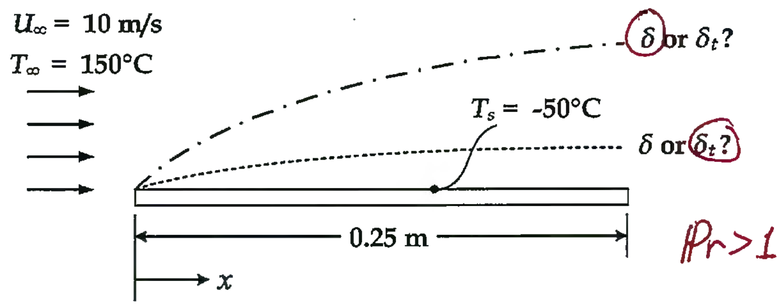
Grade: _____/20

Problem 1 (11 pts)

A fluid called Dynalene HC (ρ=1200 kg/m³, μ=2.5×10⁻³ kg/m·s, k=0.504 W/m-°C, and Pr=16) flows over a 0.25-m-long flat plate with a velocity of U_∞=10.0 m/s and temperature T_∞=150°C. The plate is maintained at T_s=-50°C. Dimensions are shown in the figure.



(a) [1 pt] At what temperature have the properties of Dynalene HC been evaluated?

$$T_f = \frac{T_s + T_\infty}{2} = \frac{-50°C + 150°C}{2} = 50°C$$ ← ANS

(b) [2 pts] Boundary layer profiles are shown in the figure. On the figure, circle which boundary layer is the velocity boundary layer thickness (δ_V) and which is the thermal boundary layer thickness (δ_T).

(c) [3 pts] Determine whether the flow is entirely laminar, entirely turbulent or whether it transitions somewhere along the plate (Note: >90% of the plate is sufficient for "entirely.")

$$Re_{cr} = 500{,}000 = \frac{\rho x_{cr} U_\infty}{\mu}$$

$$x_{cr} = \frac{Re_c \cdot \mu}{\rho U_\infty} = \frac{(500{,}000)(2.5\times10^{-3} \frac{kg}{m\cdot s})}{(1200 \frac{kg}{m^3})(10 \frac{m}{s})} = 0.10 \text{ m}$$

$x_{cr} = 0.417 L$ → Combined laminar/turbulent flow

(d) [5 pts] Determine the total average convective heat transfer coefficient between the Dynalene HC and the plate.

- Combined laminar/turbulent
- Flat plate
- T_s = const BC

$$Nu = (0.037 Re^{0.8} - 871) Pr^{1/3}$$

$$Re_L = \frac{\rho U_\infty L}{\mu} = \frac{(1200 \frac{kg}{m^3})(10 \frac{m}{s})(0.25 m)}{2.5\times10^{-3} \frac{kg}{m\cdot s}} = 1{,}200{,}000$$

$$Nu = (0.037 \cdot 1{,}200{,}000^{0.8} - 871) 16^{1/3} = 4612$$

$$Nu = \frac{hL}{k}$$

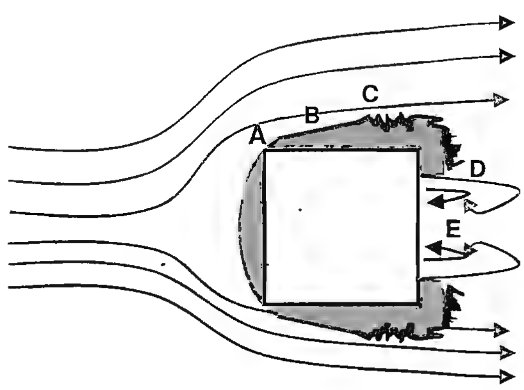
$$h = \frac{k Nu}{L} =$$

$$h = \frac{(0.504 \frac{W}{m\cdot°C})(4612)}{0.25 m} = 9297 \text{ W/m}^2\text{-°C}$$ ← ANS

Name

Problem 2 (3 pts)

Consider flow around a rod once again. The figure below shows the flow patterns around such a rod.



Choose the *best* description of what is happening at the given locations in the figure.

(a) Location B
- o A. Boundary layer detachment
- o B. Boundary layer thickening
- o C. Transition to turbulence

(b) Location C
- o A. Boundary layer detachment
- o B. Boundary layer thickening
- o C. Transition to turbulence

(c) Location D
- o A. Boundary layer detachment
- o B. Boundary layer thickening
- o C. Transition to turbulence

Problem 4 (6 pts)

(a) **True** | **False:** Biot number is $Bi=hL_c/k$ and Nusselt number is $Nu=hL_c/k$. They are therefore the same number but used differently in different applications.

(b) **True** | **False:** When Nusselt number is one ($Nu = 1$) there is no convection heat transfer.

(c) **True** | **False:** Viscous effects can be ignored inside a boundary layer.

(d) **True** | **False:** Thin thermal boundary layers produce larger heat transfer coefficients than thick boundary layers.

(e) **True** | **False:** For flow around cylinders, both frontal area and surface area can be used to find heat transfer

(f) **True** | **False:** Flow at extremely small Reynolds numbers is called "creep" in honor of the band *Radiohead*. (The answer is False, though it is true that small Reynolds number flows are called creep flows)