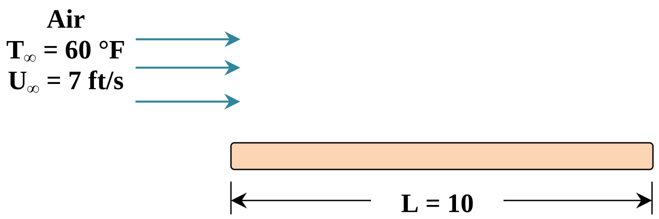
First name: …………………………….. Last name: ……………………………..

Homework

Exercise:

Air at **60°F** flows over a **10-ft-long** flat plate at **7 ft/s**. Determine:

1) the local friction coefficients (**$C_{f,x}$**) at intervals of **1 ft**, and ;
2) heat transfer coefficients (**h_x**) at intervals of **1 ft**, and ;
3) Plot the results against the distance from the leading edge.



Answer:

The properties of air at 1 atm and 60 F (≈ 15,5 °C) are from (Tables A-22, page 798 from *Yunus A. Çengel, Introduction to Thermodynamics and Heat Transfer, 2nd edition, McGraw-Hill Science/Engineering/Math (2007).*

You may also utilize "*APPENDIX A – Thermophysical properties of matters*", which is accessible on Moodle

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TABLE A–22

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m³	Specific Heat c_p, J/kg · K	Thermal Conductivity k, W/m · K	Thermal Diffusivity α, m²/s	Dynamic Viscosity μ, kg/m · s	Kinematic Viscosity ν, m²/s	Prandtl Number Pr
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296

Temp. T, °C			Temp. T, °F	
	k = 0.02476 (W/m.K)	→ x 0.57779 →		k = 0,014 31 (Btu/h.ft.°F)
	ν = 1.470 x 10^{-5} (m²/s)	→ x 10.763 →		ν = 1.582 x 10^{-4} (ft²/s)
	Pr = 0.7323	dimensionless		Pr = 0.7323

Steps:

- calculate Re_x then
- determine regime flow for each 1 feet interval, then
- calculate Nu_x (*depending to regime flow*),
- Finally, calculate h_x and $C_{f,x}$

This is for each interval.

Calculations are given in table below:

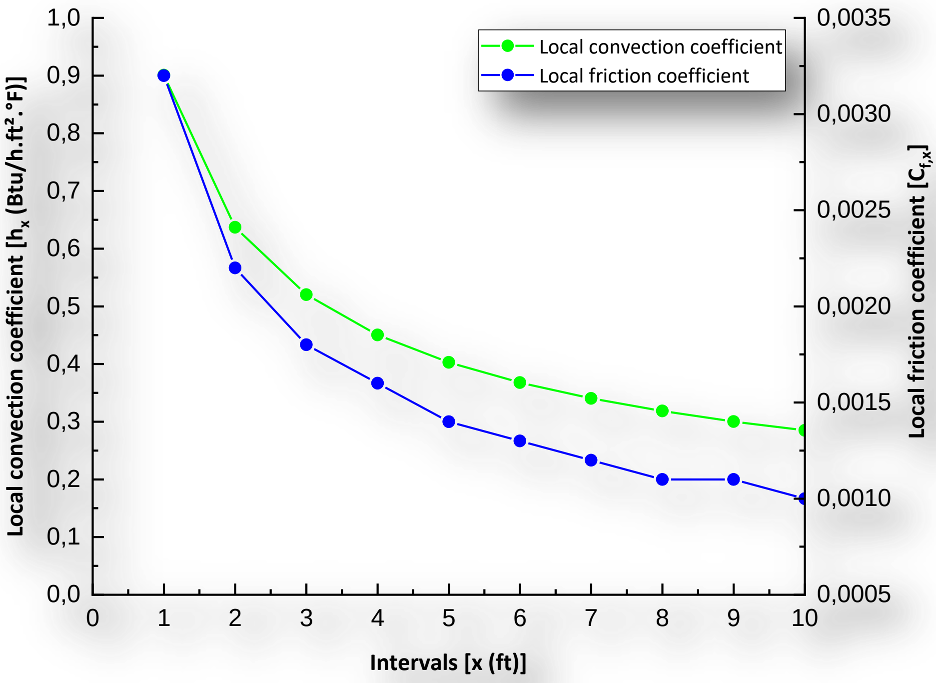
Intervals (ft)	**V** (m/s)	**L** (ft)	**ν (m²/s)**	**Re$_x$**	**Regime flow**	**Nu$_x$**	**h$_x$**	**C$_{f,x}$**
1	7	1	$1,58 \times 10^{-4}$	$4,42 \times 10^{4}$	Laminar flow	62,95	0,9008	0,0032
2	7	2	$1,58 \times 10^{-4}$	$8,85 \times 10^{4}$	Laminar flow	89,03	0,6370	0,0022
3	7	3	$1,58 \times 10^{-4}$	$1,33 \times 10^{5}$	Laminar flow	109,03	0,5201	0,0018
4	7	4	$1,58 \times 10^{-4}$	$1,77 \times 10^{5}$	Laminar flow	125,90	0,4504	0,0016
5	7	5	$1,58 \times 10^{-4}$	$2,21 \times 10^{5}$	Laminar flow	140,76	0,4029	0,0014
6	7	6	$1,58 \times 10^{-4}$	$2,65 \times 10^{5}$	Laminar flow	154,20	0,3678	0,0013
7	7	7	$1,58 \times 10^{-4}$	$3,10 \times 10^{5}$	Laminar flow	166,55	0,3405	0,0012
8	7	8	$1,58 \times 10^{-4}$	$3,54 \times 10^{5}$	Laminar flow	178,05	0,3185	0,0011
9	7	9	$1,58 \times 10^{-4}$	$3,98 \times 10^{5}$	Laminar flow	188,85	0,3003	0,0011
10	7	10	$1,58 \times 10^{-4}$	$4,42 \times 10^{5}$	Laminar flow	199,07	0,2849	0,0010

NOTE THAT: for **all intervals**, $Re_{x,i} < 5x10^5$, means that: regime flow is laminar for all intervals.
Because of that, we use **local correlations for laminar flow** below:

$$Nu_x = \frac{h_x . x}{k} = 0{,}332. Re_x^{1/2}. Pr^{1/3}$$

$$C_{f,x} = \frac{0{,}664}{Re_x^{1/2}}$$

Plotting results against the distances:



(Graphs generated using **OriginPro 2018**)