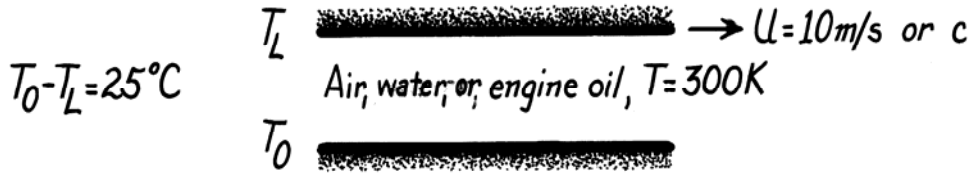
PROBLEM 6S.5

KNOWN: Velocity and temperature difference of plates maintaining Couette flow. Mean temperature of air, water or oil between the plates.

FIND: (a) Pr·Ec product for each fluid, (b) Pr·Ec product for air with plate at sonic velocity.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Couette flow, (3) Air is at 1 atm.

PROPERTIES: *Table A-4*, Air (300K, 1atm), c_p = 1007 J/kg·K, Pr = 0.707, γ = 1.4, R= 287.02 J/kg·K; *Table A-6*, Water (300K): c_p = 4179 J/kg·K, Pr = 5.83; *Table A-5*, Engine oil (300K), c_p = 1909 J/kg·K, Pr = 6400.

ANALYSIS: The product of the Prandtl and Eckert numbers is dimensionless,

$$\mathrm{Pr}\cdot\mathrm{Ec} = \mathrm{Pr}\,\frac{U^2}{c_p \Delta T} \cap \frac{m^2/s^2}{(J/kg\cdot K)K} \cap \frac{m^2/s^2}{\left(kg\cdot m^2/s^2\right)/kg}.$$

Substituting numerical values, find

	Air	*Water*	*Oil*
Pr·Ec	0.0028	0.0056	13.41

<

(b) For an ideal gas, the speed of sound is

$$c = \left(\gamma\, R\, T\right)^{1/2}$$

where R, the gas constant for air, is $R_u/\mathcal{M}$ = 8.315 kJ/kmol·K/(28.97 kg/kmol) = 287.02 J/kg·K. Hence, at 300K for air,

$$U = c = \left(1.4 \times 287.02\ \mathrm{J/kg\cdot K} \times 300\mathrm{K}\right)^{1/2} = 347.2\ \mathrm{m/s}.$$

For sonic velocities, it follows that

$$\mathrm{Pr}\cdot\mathrm{Ec} = 0.707\,\frac{(347.2\ \mathrm{m/s})^2}{1007\mathrm{J/kg\cdot K} \times 25\mathrm{K}} = 3.38.$$

<

COMMENTS: From the above results it follows that viscous dissipation effects must be considered in the high speed flow of gases and in oil flows at moderate speeds. For Pr·Ec to be less than 0.1 in air with ΔT = 25°C, U should be $\lesssim$ 60 m/s.