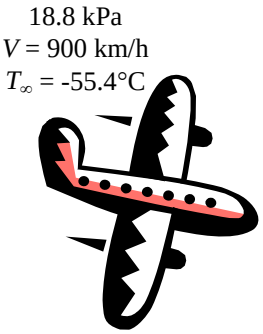
12-78 An aircraft is cruising at 900 km/h. A heating system keeps the wings above freezing temperatures. The average convection heat transfer coefficient on the wing surface and the average rate of heat transfer per unit surface area are to be determined.

Assumptions **1** Steady operating conditions exist. **2** Radiation effects are negligible. **3** Air is an ideal gas with constant properties. **4** The wing is approximated as a cylinder of elliptical cross section whose minor axis is 50 cm.

Properties The properties of air at 1 atm and the film temperature of $(T_s + T_\infty)/2 = (0\text{-}55.4)/2 = -27.7°C$ are (Table A-22)

$$k = 0.02152 \text{ W/m.°C}$$
$$\nu = 1.106\times10^{-5} \text{ m}^2/\text{s}$$
$$\text{Pr} = 0.7421$$



Note that the atmospheric pressure will only affect the kinematic viscosity. The atmospheric pressure in atm unit is

$$P = (18.8 \text{ kPa})\frac{1 \text{ atm}}{101.325 \text{ kPa}} = 0.1855 \text{ atm}$$

The kinematic viscosity at this atmospheric pressure is

$$\nu = (1.106\times10^{-5} \text{ m}^2/\text{s})/0.1855 = 5.961\times10^{-5} \text{ m}^2/\text{s}$$

Analysis The Reynolds number is

$$\text{Re} = \frac{VD}{\nu} = \frac{[(900\times1000/3600) \text{ m/s}](0.5 \text{ m})}{5.961\times10^{-5} \text{ m}^2/\text{s}} = 2.097\times10^6$$

The Nusselt number relation for a cylinder of elliptical cross-section is limited to Re < 15,000, and the relation below is not really applicable in this case. However, this relation is all we have for elliptical shapes, and we will use it with the understanding that the results may not be accurate.

$$Nu = \frac{hD}{k} = 0.248\,\text{Re}^{0.612}\,\text{Pr}^{1/3} = 0.248(2.097\times10^6)^{0.612}(0.7241)^{1/3} = 1660$$

The average heat transfer coefficient on the wing surface is

$$h = \frac{k}{D}Nu = \frac{0.02152 \text{ W/m.°C}}{0.5 \text{ m}}(1660) = \mathbf{71.45 \text{ W/m}^2\text{.°C}}$$

Then the average rate of heat transfer per unit surface area becomes

$$\dot{q} = h(T_s - T_\infty) = (71.45 \text{ W/m}^2\text{.°C})[0-(-55.4)]°C = \mathbf{3958 \text{ W/m}^2}$$

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