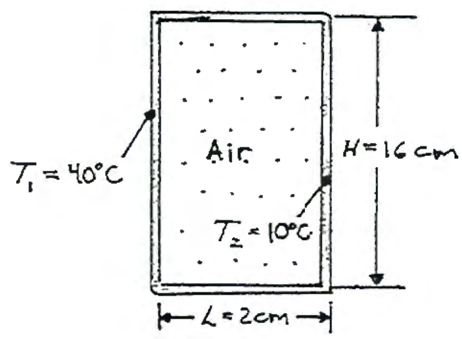
Solution
Name

Grade: ______/20

Problem 1 [10 pts]

Air is contained in an enclosure with the dimensions shown in the figure. The enclosure width (into the page) is w=0.5 m. Some properties of air are also given.



Air properties

- ν=1.561×10^{-5} m^2/s
- k=0.02551 W/m-K
- Pr=0.7281

(a) [2 pts] Which of the following give a correct expression for the rate of heat transfer in the enclosure? **Check all that apply.**

- ☐ A. $\dot{Q} = \dfrac{T_1 - T_2}{\dfrac{L}{kwH}}$
- ☑ B. $\dot{Q} = \dfrac{T_1 - T_2}{\dfrac{L}{k_{eff}wH}}$
- ☐ C. $\dot{Q} = h(T_1 - T_2)$
- ☐ D. $\dot{Q} = k_{eff}wH(T_1 - T_2)$
- ☑ E. $\dot{Q} = \dfrac{k_{eff}}{L} \cdot wH(T_1 - T_2)$

(b) [8 pts] Find the effective thermal conductivity (in W/m-K) of the air in the enclosure.

$$k_{eff} = k\,Nu$$

$$Ra = \frac{g\beta(T_1 - T_2)L^3}{\nu^2}Pr \qquad \beta = \frac{1}{T_{av}} = \frac{1}{(T_1+T_2)/2} = \frac{1}{(25+273)K}$$

$$= 0.00336\ K^{-1}$$

$$= \frac{9.81\frac{m^2}{s^2} \cdot 0.00336\frac{1}{K}(40-10)°C \cdot 0.02^3 m^3}{(1.561\times10^{-5})^2 \frac{m^4}{s^2}} \cdot 0.7281$$

$$= 23{,}607$$

$$\frac{H}{L} = \frac{16\ cm}{2\ cm} = 8$$

$$\rightarrow Nu = 0.22\left(\frac{Pr}{0.2+Pr}Ra\right)^{0.28}\left(\frac{H}{L}\right)^{-1/4}$$

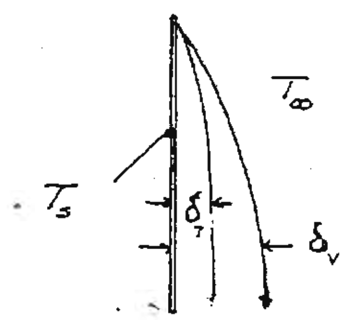
$$= 2.18$$

$$k_{eff} = (2.18)\left(0.02551\frac{W}{m^2 \cdot K}\right)$$

$$= 0.0556 \leftarrow \text{ANS}$$

Problem 2 [6 pts]

The velocity and thermal boundary layers for and unknown gas next to a vertical plate are shown in the figure.



(a) [2pts] How does the temperature of the surface compare to the ambient gas temperature?

- A. $T_s < T_\infty$
- B. $T_s = T_\infty$
- C. $T_s > T_\infty$
- D. Cannot be determined

(b) [2pts] What is the Prandtl number for the gas?

- A. $Pr < 1$
- B. $Pr \approx 1$
- C. $Pr > 1$
- D. Cannot be determined

(c) [2pts] How does the heat flux at the middle of the plate compare to that at the top of the plate?

- A. $q_{middle} < q_{top}$
- B. $q_{middle} = q_{top}$
- C. $q_{middle} > q_{top}$
- D. Cannot be determined

Problem 3 [4 pts]

(a) [1 pt] Gravity on the moon is approximately one sixth of the gravity on earth. We would therefore expect that natural convection within a lunar lander to be

- A. less than that on earth
- B. the same as that on earth
- C. greater than that on earth

(a) [1 pt] Air blows over an inclined plate with a velocity of $U = 2$ m/s. You calculate the Gr/Re^2 be 0.2. How do you treat the resulting convection?

- A. Forced convection only
- B. Natural convection only
- C. Combined forced/natural convection

(b) [2 pt] The velocity in part (b) is doubled to $U = 4$ m/s. All other conditions are the same. How do you treat the resulting convection?

- A. Forced convection only
- B. Natural convection only
- C. Combined forced/natural convection

$$\frac{Gr}{Re_2^2} = \frac{Gr}{Re_1^2} \cdot \left(\frac{U_1^2}{U_2^2}\right) = 0.2 \left[\frac{2^2 m^2/s^2}{4^2 m^2/s^2}\right]$$

$$= 0.05 < 0.1.$$