$\mathcal{ECE}$*309*
Thermodynamics & Heat Transfer

Quiz #2:

Name:	______________________
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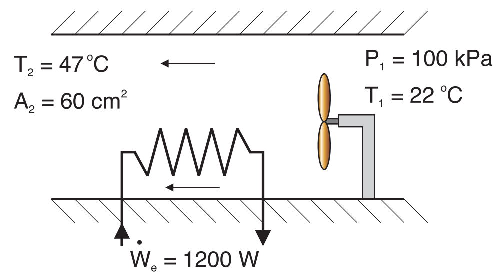
Problem: A hair dryer is basically a duct in which a few layers of electric resistors are placed. A small fan pulls the air in and forces it through the resistors where it is heated. Air enters $\mathbf{1200}\ \boldsymbol{W}$ hair dryer at $\mathbf{100}\ \boldsymbol{kPa}$ and $\mathbf{22}\ \boldsymbol{^\circ C}$ and leaves at $\mathbf{47}\ \boldsymbol{^\circ C}$. The cross-sectional area of the dryer at the exit is $\mathbf{60}\ \boldsymbol{cm^2}$. Neglecting the power consumed by the fan and the heat losses through the walls of the hair dryer, determine:



a) the volume flow rate of air at the inlet
b) the velocity of the air at the exit

Assumptions

1. steady state, steady flow process
2. air is an ideal gas
3. $\boldsymbol{\Delta KE = \Delta PE = 0}$
4. the power consumed by the fan is negligible
5. the heat loss to the surroundings is negligible

Properties
From Table A-1, the gas contant for air is $\boldsymbol{R = 0.287\ kJ/kg \cdot K}$

From Table A-2, the specific heat of air at room temperatur is given as $\boldsymbol{C_p = 1.005\ kJ/kg \cdot K}$

Part a)
Since there is only one flow path, we know from conservation of mass that

$$\dot{m}_1 = \dot{m}_2 = \dot{m}$$

From conservation of energy (assuming that $\boldsymbol{\Delta KE = \Delta PE = 0}$)

$$\dot{m} h_1 + \dot{W}_e = \dot{m} h_2$$

or

$$\dot{W}_e = \dot{m}(h_2 - h_1) = \dot{m} C_p (T_2 - T_1)$$

The mass flow rate of the air is calculated as

$$\dot{m} = \frac{\dot{W}_e}{C_p(T_2 - T_1)} = \frac{1.2\ kJ/s}{(1.005\ kJ/kg \cdot K)(47 - 22)\ ^\circ C} = 0.04776\ kg/s$$

The specific volume of the air can be determined using the ideal gas equation

$$v_1 = \frac{RT_1}{P_1} = \frac{(0.287\ kJ/kg\cdot K)(295\ K)\left(\frac{1kPa\cdot m^3}{1\ kJ}\right)}{100\ kPa} = 0.8467\ m^3/kg$$

Finally, the volumetric flow rate is calculated as

$$\dot{V}_1 = \dot{m}v_1 = (0.04776\ kg/s)(0.8467\ m^3/kg) = 0.0404\ m^3/s \ \Leftarrow \textbf{part a)}$$

Part b)

The mass flow rate of air at the exit is given as

$$\dot{m} = \rho_2 A_2 \mathcal{V}_2 = \frac{A_2\mathcal{V}_2}{v_2}$$

The specific volume at the exit is

$$v_2 = \frac{RT_2}{P_2} = \frac{(0.287\ kJ/kg\cdot K)(320\ K)\left(\frac{1kPa\cdot m^3}{1\ kJ}\right)}{100\ kPa} = 0.9184\ m^3/kg$$

and

$$\mathcal{V}_2 = \frac{\dot{m}v_2}{A_2} = \frac{(0.04776\ kg/s)(0.9184\ m^3/kg)}{60\times 10^{-4}m^2} = 7.31\ m/s \ \Leftarrow \textbf{part b)}$$