Thermodynamics 1 (MEP 261)

Midterm Exam #1 (30 Marks)
Model Answer
Class ZA, Date: November 23, 2011

Name: **University ID:**

1) Determine the pressure exerted on a diver at 30 m below the free surface of the sea. Assume a barometric pressure of 101 kPa and a specific gravity of 1.03 for seawater.

5 Marks

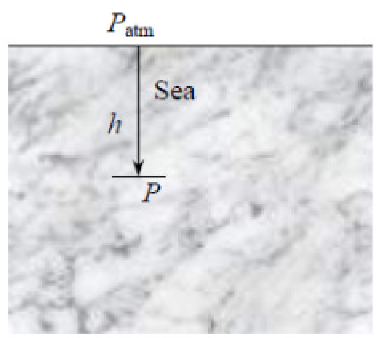
Solution A diver is moving at a specified depth from the water surface. The pressure exerted on the surface of the diver by water is to be determined.

Assumption The variation of the density of water with depth is negligible.

Properties The specific gravity of seawater is given to be SG = 1.03. We take the density of water to be 1000 kg/m^3.

Analysis The density of the seawater is obtained by multiplying its specific gravity by the density of water which is taken to be 1000 kg/m^3:

$$\rho = \text{SG} \times \rho_{H_2O} = (1.03)(1000\ \text{kg/m}^3) = 1030\ \text{kg/m}^3$$



The pressure exerted on a diver at 30 m below the free surface of the sea is the absolute pressure at that location:

$$\begin{aligned} P &= P_{atm} + \rho g h \\ &= (101\ \text{kPa}) + (1030\ \text{kg/m}^3)(9.807\ \text{m/s}^2)(30\ \text{m})\left(\frac{1\ \text{kPa}}{1000\ \text{N/m}^2}\right) \\ &= \mathbf{404.0\ kPa} \end{aligned}$$

2) A fan is to accelerate quiescent air to a velocity of 10 m/s at a rate of 4 m^3/s. Determine the minimum power that must be supplied to the fan. Take the density of air to be 1.18 kg/m^3.

5 Marks

Solution A fan is to accelerate quiescent air to a specified velocity at a specified flow rate. The minimum power that must be supplied to the fan is to be determined.

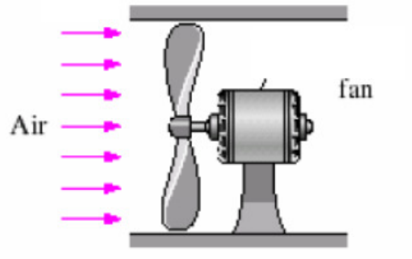
Assumption The fan operates steadily.

Properties The density of air is given to be $\rho = 1.18$ kg/m^3.

Analysis A fan transmits the mechanical energy of the shaft (shaft power) to mechanical energy of air (kinetic energy). For a control volume that encloses the fan, the energy balance can be written as

$$\underbrace{\dot{E}_{in} - \dot{E}_{out}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{dE_{\text{system}} / dt^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} = 0 \quad \rightarrow \quad \dot{E}_{in} = \dot{E}_{out}$$

$$\dot{W}_{\text{sh, in}} = \dot{m}_{\text{air}} \text{ke}_{\text{out}} = \dot{m}_{\text{air}} \frac{V_{\text{out}}^2}{2}$$



where

$$\dot{m}_{\text{air}} = \rho \dot{V} = (1.18 \text{ kg/m}^3)(4 \text{ m}^3\text{/s}) = 4.72 \text{ kg/s}$$

Substituting, the minimum power input required is determined to be

$$\dot{W}_{\text{sh, in}} = \dot{m}_{\text{air}} \frac{V_{\text{out}}^2}{2} = (4.72 \text{ kg/s}) \frac{(10 \text{ m/s})^2}{2} \left(\frac{1 \text{ J/kg}}{1 \text{ m}^2\text{/s}^2} \right) = 236 \text{ J/s} = \mathbf{236 \text{ W}}$$

Discussion The conservation of energy principle requires the energy to be conserved as it is converted from one form to another, and it does not allow any energy to be created or destroyed during a process. In reality, the power required will be considerably higher because of the losses associated with the conversion of mechanical shaft energy to kinetic energy of air.

3) Complete the following table for H_2O

T, °C	p, kPa	u, kJ/kg	v, m^3/kg	Phase description	x
	400	**1450**			
220				**Saturated vapor**	
190	**2500**				
	4000	**3040**			

10 Marks

Solution *Complete the following table for H_2O:*

T, °C	P, kPa	u, kJ / kg	Phase description
143.61	400	1450	***Saturated mixture***
220	***2319.6***	***2601.3***	Saturated vapor
190	2500	***805.15***	***Compressed liquid***
466.21	4000	3040	***Superheated vapor***

4) A frictionless piston–cylinder device initially contains 200 L of saturated liquid refrigerant-134a. The piston is free to move, and its mass is such that it maintains a pressure of 900 kPa on the refrigerant. The refrigerant is now heated until its temperature rises to 70°C. Calculate the work done during this process. **5 Marks**

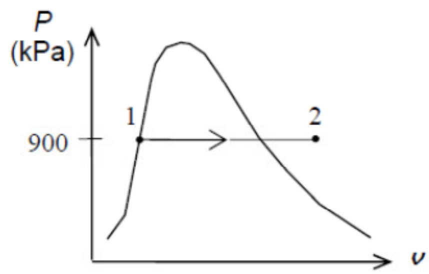
Solution Refrigerant-134a in a cylinder is heated at constant pressure until its temperature rises to a specified value. The boundary work done during this process is to be determined.

Assumption The process is quasi-equilibrium.

Properties Noting that the pressure remains constant during this process, the specific volumes at the initial and the final states are (Tables A-11 through A-13)

$$\left.\begin{array}{l} P_1 = 900 \text{ kPa} \\ \text{Sat. liquid} \end{array}\right\} v_1 = v_{f\,@900\text{ kPa}} = 0.0008580 \text{ m}^3/\text{kg}$$

$$\left.\begin{array}{l} P_2 = 900 \text{ kPa} \\ T_2 = 70°\text{C} \end{array}\right\} v_2 = 0.027413 \text{ m}^3/\text{kg}$$



Analysis The boundary work is determined from its definition to be

$$m = \frac{V_1}{v_1} = \frac{0.2 \text{ m}^3}{0.0008580 \text{ m}^3/\text{kg}} = 233.1 \text{ kg}$$

and

$$W_{b,\text{out}} = \int_1^2 P\,dV = P(V_2 - V_1) = mP(v_2 - v_1)$$

$$= (233.1 \text{ kg})(900 \text{ kPa})(0.027413 - 0.0008580)\text{m}^3/\text{kg}\left(\frac{1 \text{ kJ}}{1 \text{ kPa}\cdot\text{m}^3}\right)$$

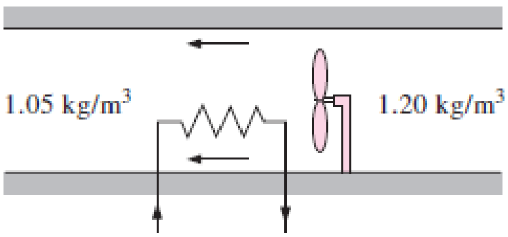
$$= \mathbf{5571\ kJ}$$

Discussion The positive sign indicates that work is done by the system (work output).

5)

5) A hair dryer is basically a duct of constant diameter 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. If the density of air is 1.20 kg/m^3 at the inlet and 1.05 kg/m^3 at the exit, determine the percent increase in the velocity of air as it flows through the dryer.

5 Marks

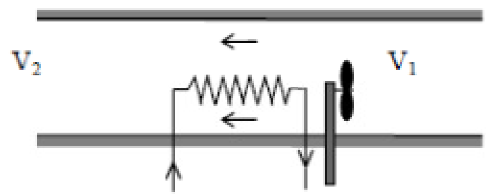


Solution Air is expanded and is accelerated as it is heated by a hair dryer of constant diameter. The percent increase in the velocity of air as it flows through the dryer is to be determined.

Assumption Flow through the nozzle is steady.

Properties The density of air is given to be 1.20 kg/m^3 at the inlet, and 1.05 kg/m^3 at the exit.

Analysis There is only one inlet and one exit, and thus $\dot{m}_1 = \dot{m}_2 = \dot{m}$. Then,



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

$$\rho_1 A V_1 = \rho_2 A V_2$$

$$\frac{V_2}{V_1} = \frac{\rho_1}{\rho_2} = \frac{1.20\,\text{kg/m}^3}{1.05\,\text{kg/m}^3} = 1.14 \quad \text{(or, and increase of 14\%)}$$

Therefore, the air velocity increases 14% as it flows through the hair dryer.