Zachary Ahmad
PSE 380
Due 4/19/21

4.7) An underwater turbine extracts a fraction of the kinetic energy from the ocean current. How do the temperature and water velocity influence the power? Hint: write the power term as mass flow rate times specific work.

$P = \dot{W} = \dot{m} \times w$. specific work $w = \frac{1}{2} f V^2$

$\dot{m} = \rho A V$ so power is $P = \frac{1}{2} \rho A V^3$

Since temperature of the water enters the turbine with density, and we assume that density remains constant since water is incompressable, power does not vary with temperature.

- I understand how to solve this problem.

Zachary Ahmad
PSE 580
Due: 4/19/21

4.11) A large brewery has a pipe of cross-sectional area 0.2 m^2 flowing carbon dioxide at 400 kPa, 10°C with a volume flow rate of 0.3 m^3/s. Find the velocity and the mass flow rate.

$A = 0.2 m^2$
$P = 400 kPa$
$T = 10°C = 283 K$

CO_2, Table A.5, $R = 0.1889 \, kJ/kg \cdot K$
$\dot{Q} = 0.3 \, m^3/s$
assuming ideal gas

$$\rho = \frac{P}{RT} \rightarrow \frac{400}{0.1889 \cdot 283} = 7.482 \, kg/m^3$$

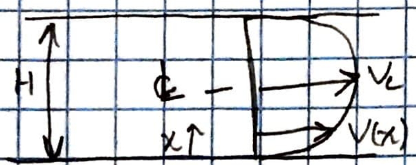
Mass flow rate: $\dot{m} = \rho \dot{Q}$
$= (7.482)(0.3)$
$= \underline{2.2446 \, kg/s}$

Volume flow rate: $\dot{Q} = A \cdot V$
$$V = \frac{\dot{Q}}{A} = \frac{0.3}{0.2}$$
$= \underline{1.5 \, m/s}$

• I understand how to solve this problem.

Zachary Ahmad
FSCI 380
Due 4/19/21

4.15) A flat channel of depth 1 m has a fully developed laminar flow of air at P_0, T_0 with a velocity profile of $V = 4V_c x(H-x)/H^2$, where V_c is the velocity on the centerline and x is the distance across the channel, as shown below. Find the total mass flow rate and the average velocity both as functions of V_c and H.



Total Discharge $= Q = \int V\,dA = \int_0^H V\,dx =$

$$\int_0^H \frac{4V_c(H-x)}{H}\,dx = 2V_c(2-H)$$

$$\rho = \frac{P_0}{RT_0} \qquad \rho Q = \frac{P_0}{RT_0}\left(2V_c(2-H)\right)$$

Average velocity $= Q/A = \dfrac{Q}{(H\cdot 1)} = 2V_c\dfrac{(2-H)}{H}$

· I do not fully understand how to solve this.

Zachary Ahmad
PSE 380
Due 4/19/21

4.21) A nozzle receives an ideal gas flow with a velocity of 25 m/s, and the exit at 100 kPa, 300 K velocity is 250 m/s. Determine the inlet temperature if the gas is argon, helium, or nitrogen.

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}, \quad C_p T_1 + \frac{V_1^2}{2} = C_p T_2 + \frac{V_2^2}{2}$$

Table A.5

$$T_1 = T_2 + \frac{1}{C_p}\left(\frac{V_2^2}{2} - \frac{V_1^2}{2}\right)$$

argon, $C_p = 0.52$ kJ/kg K

$$= 300 + \frac{1}{0.52\times10^3}\left(\frac{250^2}{2} - \frac{25^2}{2}\right)$$

$$= \boxed{359.49°C}$$

helium, $C_p = 5.913$ kJ/kg K

$$= 300 + \frac{1}{5.913\times10^3}\left(\frac{250^2}{2} - \frac{25^2}{2}\right)$$

$$= \boxed{305.96°C}$$

nitrogen, $C_p = 1.042$ kJ/kg K

$$= 300 + \frac{1}{1.042\times10^3}\left(\frac{250^2}{2} - \frac{25^2}{2}\right)$$

$$= \boxed{329.70°C}$$

- I understand how to solve this problem.

4

Zachary Ahmad
PSE 380
Due 4/19/21

4.30) The front of a jet engine acts similarly to a diffuser, receiving air at 900 km/h, -5°C, and 50 kPa, bringing it to 80 m/s relative to the engine before entering the compressor (see below). If the flow area is increased to 120% of the inlet area, find the temperature and pressure in the compressor inlet.

continuity eq: $\dot{m}_i = \dot{m}_e = \frac{AV}{v}$

$\dot{m}_i(h_i + \frac{1}{2}V_i^2) = \dot{m}_e(\frac{1}{2}V_e^2 + h_e)$, $h_e - h_i = C_p(T_e - T_i) = \frac{1}{2}V_i^2 - \frac{1}{2}V_e^2$

$= \frac{1}{2}\left(\frac{900 \times 1000}{3600}\right)^2 - \frac{1}{2}(80)^2$, $h_e - h_i = 28050 \text{ J/kg} = 28.05 \text{ kJ/kg}$

$\Delta T = \frac{28.05}{1.004} = 27.9$, $T_e = -5 + 27.9 = \boxed{22.9°C}$

$V_e = V_i \times \frac{1.2 \times 80}{1 \times 250} = V_i \times 0.384$

$PV = RT \rightarrow V_e = \frac{RT_e}{P_e} = \frac{RT_i(0.384)}{P_i}$

$P_e = P_i\left(\frac{T_e}{T_i}\right)\frac{1}{0.384} = 50\left(\frac{295.9}{268}\right)\frac{1}{0.384} = \boxed{143.763 \text{ KPa}}$

- I understand how to solve this problem.

5

Zachary Ahmad
PSE 380
Due 4/19/21

4.31) R-410a at -5°C, 700 kPa is throttled, so it becomes cold at -40°C. What is exit P?

Table B.4.1, $h_i = 50.22$ kJ/kg @ -5°C, 700 kPa
$h_f = 0$ kJ/kg, $h_g = 262.83$ kJ/kg, $P_{sat} = 175$ kPa
@ -40°C

$h_e = h_i = 50.22$ kJ/kg $\quad h_f < h_e < h_g$

so pressure at state 2 is equal to saturation pressure at corresponding temp at state 2.

$$P_e = P_{sat} = \boxed{175 \text{ kPa}}$$

• I understand how to solve this problem.

(1)

Zachary Ahmad
PSE 380
Due: 4/19/21

4.35) Carbon dioxide used as a natural refrigerant flows out of a cooler at 10 MPa, 40°C, after which it is throttled to 1.4 MPa. Find the state (T, x) for the exit flow.

$T_i = 40°C$, $P_i = 10$ MPa, $P_e = 1.4$ MPa

$h_e + \frac{1}{2}V_e^2 = h_i + \frac{1}{2}V_i^2$ $\quad v_e = v_i \quad h_i = h_e = 200.14$ kJ/kg
↳ Table B.3.2

@ P = 1334.2 kPa, T = -32°C, $h_f = 16.3$ kJ/kg, $h_{fg} = 307.42$ kJ/kg
Table B.3.1

@ P = 1427.8 kPa, T = -30°C, $h_f = 20.43$ kJ/kg, $h_{fg} = 303.48$ kJ/kg

interpolation

$$T_e = -32 + \frac{1400 - 1334.2}{1427.8 - 1334.2}(-30 + 32) = \boxed{-30.6\,°C}$$

$$h_f = 16.3 + \frac{1400 - 1334.2}{1427.8 - 1334.2}(20.43 - 16.3) = \boxed{19.20 \text{ kJ/kg}}$$

$$h_{fg} = 307.42 + \frac{1400 - 1334.2}{1427.8 - 1334.2}(303.48 - 307.42) = \boxed{304.65 \text{ kJ/kg}}$$

$$x_e = \frac{h_e - h_f}{h_{fg}} = \frac{200.14 - 19.20}{304.65} = \boxed{0.594}$$

- I understand how to solve this problem.

7

Zachary Ahmad
PSE 380
Due: 4/19/21

4.40) A steam turbine has an inlet of 3 kg/s water at 1200 kPa and 350°C with a velocity of 15 m/s. The exit is at 100 kPa, 150°C and very low velocity. Find the specific work and the power produced.

$T_i = 350°C \quad T_e = 150°C \quad P_i = 1.2\,MPa \quad P_e = 100\,kPa$

$\dot{m} = 3\,\frac{kg}{s} \quad V_i = 15\,m/s \quad h_e + \frac{1}{2}V_e^2 + w = h_i + \frac{1}{2}V_i^2$

$V_e \approx 0$

$w = h_i - h_e + \frac{1}{2}V_i^2$

Table B.1.3,
@ $P_i = 1200\,kPa$, $T_i = 350°C$
$h_i = 3153.59\,kJ/kg$

Table B.1.3
@ $P_e = 100$, $T_e = 150°C$
$h_e = 2776.38\,kJ/kg$

$w = 3153.59 - 2776.38 + \frac{1}{2}(15)^2/1000 = \boxed{377.3\,kJ/kg}$

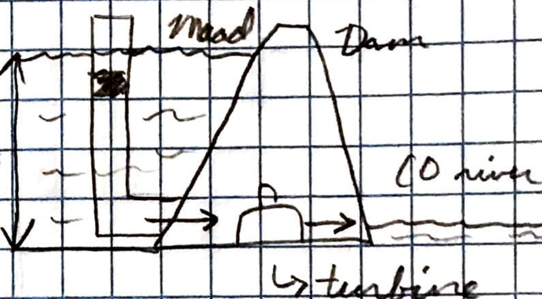
conversion

$P = \dot{W} = \dot{m}w = 3(377.3) = \boxed{1132\,kW}$

8

Zachary Ahmad
PSE 380
Due: 4/19/21

4.47) Hoover Dam across the Colorado River dams up Lake Mead 200m higher than the river downstream (see below). The electric generators driven by water-powered turbines deliver 1300 MW of power. If the water is 17.5°C, find the minimum amount of water running through the turbines.



continuity: $\dot{m}_i = \dot{m}_e$

$$\left(h + \tfrac{1}{2}V^2 + gz\right)_i = \left(h + \tfrac{1}{2}V^2 + gz\right)_e + w_T$$

$h_i \cong h_e$, $V_i \cong V_e$

$$w_T = gz_i - gz_e = \frac{9.81 \times 200}{1000} = 1.961 \text{ kJ/kg}$$

$$\dot{m} = \frac{\dot{W}_T}{w_T} = \frac{1300 \times 10^3 \text{ kW}}{1.961 \text{ kJ/kg}} = 6.63 \times 10^5 \text{ kg/s}$$

$$\dot{V} = \dot{m}v = 6.63 \times 10^5 \times 0.001 = \boxed{664 \text{ m}^3/\text{s}}$$

- I understand how to solve this problem.

Zachary Ahmad
PSE 380
Due: 4/19/21

4.53) A refrigerator uses the natural refrigerant carbon dioxide where the compressor brings 0.02 kg/s from 1 MPa, -20°C to 6 MPa using 2 kW of power. Find the compressor exit temperature.

$$\left(h+\frac{1}{2}V^2\right)_e + w = \left(h+\frac{1}{2}V^2\right)$$

$V_e = V_i = 0$, $w = h_i - h_e$

steady state

From table B.3.1, for $P_i = 1000\,kPa$ and $T_i = -20°C$, enthalpy is $h_i = 342.31\ kJ/kg$

$$h_e = h_i - w = h_i - \frac{\dot{W}}{\dot{m}} = 342.31 - \frac{2}{0.02} = \boxed{442.31\ kJ/kg}$$

Table B.3.1, @ $P_e = 6000\,kPa$ and $421.69\ kJ/kg = h$, $T = 100°C$

B.3.1, @ $P_e = 6000\,kPa$, $h = 445.02\ kJ/kg$, $T = 120°C$

$$T_e = 100 + \frac{442.31 - 421.69}{445.02 - 421.69}(120-100)$$

$$= \boxed{117.7°C}$$

• I understand how to solve this problem.

10

Zachary Ahmad
PSE 380
Due: 4/19/21

4.(62) The air conditioner in a house or car has a cooler that brings atmospheric air from 30°C to 10°C, both states at 101 kPa. For a flow rate of 0.75 kg/s find the rate of heat transfer.

Table A.5 $C_p = 1.004$ kJ/kgK

$$\dot{Q} = \dot{m} C_p (T_1 - T_2)$$

$$\dot{Q} = (0.75)(1.004)(30-10)$$

$$\dot{Q} = 15.075 \text{ KW}$$

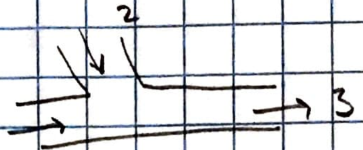
• I understand how to solve this problem.

Zachary Ahmad
PSE 380
Due: 4/19/21

4.104) Two flows of air are both at 200 kPa; one has 1 kg/s at 400 K and the other has 2 kg/s at 290 K. The two flows are mixed together in an insulated box to produce a single exit flow at 200 kPa. Find the exit temperature.

$\dot{m}_1 + \dot{m}_2 = \dot{m}_3 = 1 + 2 = 3\ kg/s$

$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$



$\dot{m}_1 s_1 + \dot{m}_2 s_2 + \dot{S}_{gen} = \dot{m}_3 s_3$ → entropy

$$T_3 = (\dot{m}_1/\dot{m}_3) T_1 + (\dot{m}_2/\dot{m}_3) T_2$$
$$= \frac{1}{3}(400) + \frac{2}{3}(290) = \boxed{326.67\ K}$$

$$\dot{S}_{gen} = \dot{m}_1 (s_3 - s_1) + \dot{m}_2 (s_3 - s_2)$$
$$= 1 \times 1.004 \ln\left(\frac{326.67}{400}\right) + 2 \times 1.004 \ln\left(\frac{326.67}{290}\right)$$
$$= \boxed{0.0358\ kW/K}$$

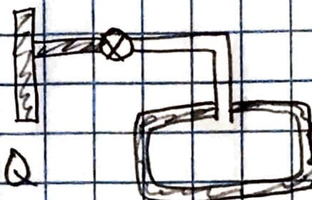
- I do not fully understand how to solve this

(12)

Zachary Ahmad
PSE 380
Due: 4/19/21

4.126) An initially empty cylinder is filled with air from 20°C, 100 kPa until it is full. Assuming no heat transfer, is the final temperature above, equal to, or below 20°C? Does the final T depend on the size of the cylinder?

$T_1 = 20°C$, $P_1 = 100\,kPa$



$m_2 u_2 - 0 = m_1 u_1 - W + Q$

$m_2 u_2 = h_1$

$m_i h_i + 0 - 0$

$u_2 = h_1$

so $P_1 = P_2 = 100\,kPa$

Final temp is above initial temp.

$T_2 > T_1$ so it does not depend on volume.

· I understand how to solve this problem.