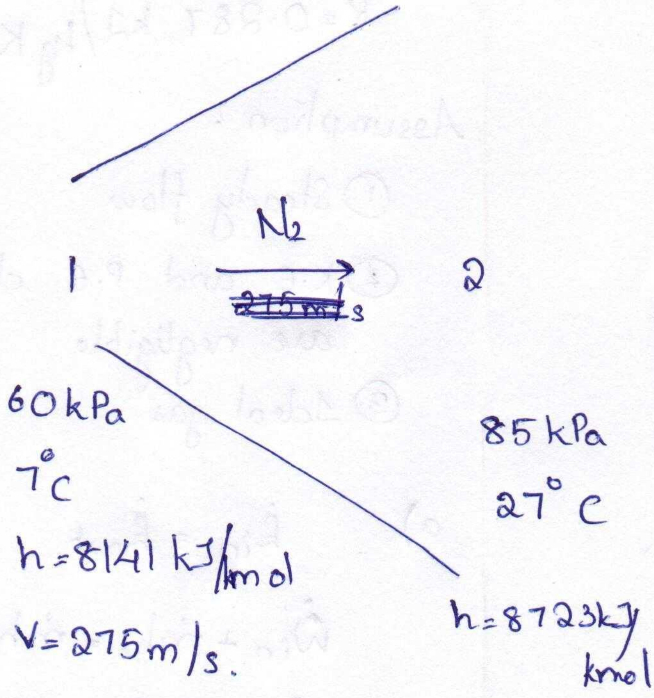
AS1300:

Tutorial 3 solution.

1.

$M_{N_2} = 28\ kg/kmol$



Assumptions:

1. Steady flow
2. Ideal gas
3. P.E change is negligible
4. Heat transfer negligible
5. No work interactions

$\dot{m}_{in} = \dot{m}_{out} \Rightarrow \dot{m}_1 = \dot{m}_2$

$\dot{E}_{in} = \dot{E}_{out}$

$$\Rightarrow \dot{m}_1 (h_1 + V_1^2/2) = \dot{m}_2 (h_2 + V_2^2/2)$$

$\dot{Q} = 0$
$\dot{W} = 0$
$\Delta P.E = 0$

$$\Rightarrow h_2 - h_1 + \frac{V_2^2 - V_1^2}{2} = 0$$

$$\frac{8723 - 8141\ kJ/kmol}{28\ kg/kmol} + \frac{V_2^2 - (275)^2}{2}\ J/kg = 0$$

$$\Rightarrow \boxed{V_2 = 185\ m/s}$$

$\dot{m}_1 = \dot{m}_{out}$

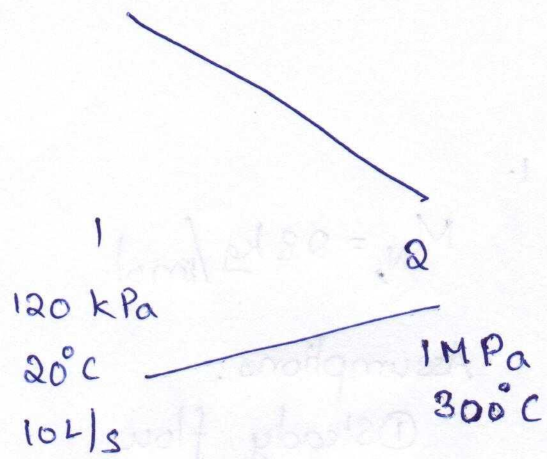
$\Rightarrow \rho_1 A_1 V_1 = \rho_2 A_2 V_2$

$$\frac{A_1}{A_2} = \frac{\rho_2 V_2}{\rho_1 V_1} = \frac{(P_2/RT_2) V_2}{(P_1/RT_1) V_1} = \frac{85/300}{60/280} \times \frac{185}{275} = 0.887$$

2. Given

$C_p = 1.018\ kJ/kg\,K$

$R = 0.287\ kJ/kg\,K$



Assumption :

① Steady flow

② K.E and P.E changes are negligible

③ Ideal gas

a) $\dot{E}_{in} = \dot{E}_{out}$, $\dot{m}_1 = \dot{m}_2 = \dot{m}$

$\dot{W}_{in} + \dot{m}h_1 = \dot{m}h_2$

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

$\therefore W_{in} = 1.018\ kJ/kg\,K\ (300-20)\,K = 285\ kJ/kg.$

b) $v_1 = \dfrac{RT_1}{P_1} = \dfrac{0.287\ m^3\,kPa/kg\,K \times (293\,K)}{120\ kPa}$

$= 0.7008\ m^3/kg$

and $\dot{m} = \dfrac{\dot{V}_1}{v_1} = \dfrac{0.01\ m^3/s}{0.7008\ m^3/kg} = 0.0143\ kg/s$

Power

$\Rightarrow \dot{W}_{in} = \dot{m}\,C_p(T_2 - T_1)$

$= 0.0143 \times 285 = 4.068\ kW.$

3. $C_p = 1.018 \text{ kJ/kg K}$

$R = 0.287 \text{ kPa m}^3/\text{kg K}$

$\dot{W}_e = 1500\text{W}$

1 — 2

$P_1 = 100\text{kPa}$, $T_1 = 300\text{K}$

$T_2 = 80°C$, $V_2 = 21\text{m/s}$

Assumptions :

same as ②.

a) $\dot{E}_{in} = \dot{E}_{out}$

$$\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) + \dot{W}_{in} = \dot{m}\left(h_2 + \frac{V_2^2}{2}\right)$$

$$\dot{m} = \frac{\dot{W}_{in}}{(h_2 - h_1) + \left(\frac{V_2^2 - V_1^2}{2}\right)} = \frac{1.5 \times 10^3 \text{ W}}{(1.018)(353-300) + \frac{21^2}{2} \times \frac{1}{1000}}$$

$$= 0.028 \text{ kg/s}$$

b) $$v_2 = \frac{RT_2}{P_2} = \frac{0.287 \text{ kPa m}^3/\text{kg K} \times 353\text{K}}{100 \text{ kPa}}$$

$$= 1.013 \text{ m}^3/\text{kg}.$$

$$\dot{V}_2 = \dot{m} v_2 = 0.028 \text{ kg/s} \times 1.013 \text{ m}^3/\text{kg} = 0.0284 \text{ m}^3/\text{s}.$$

4. $P_c = 105 \text{ kPa}$; $T_c = 7°C$; $\dot{V}_c = 0.75 \text{m}^3/\text{s}$ Cold

$T_w = 34°C$; $P_w = 105 \text{ kPa}$ Warm

$T_0 = 24°C$; $\dot{m}_w / \dot{m}_c = 2.2$ Out

$C_p = 1.018 \ kJ/kg\,K$

$R = 0.287 \ kJ/kg\,K.$

a) $T_{inlet} = ?$ b) $\dot{Q}_{gain} = ?$

$\dot{E}_{in} = \dot{E}_{out}$

$\Rightarrow \dot{m}_c h_c + \dot{m}_w h_w = \dot{m}_{inlet} h_{inlet}$

$\dot{m}_c + \dot{m}_h = \dot{m}_{inlet}$

$\dot{m} + 2.2\dot{m} = \dot{m}_{inlet}$

$\dot{m}_{inlet} = 3.2\dot{m}$

$\Rightarrow \dot{m} h_c + 2.2\dot{m} h_w = 3.2\dot{m}\, h_{inlet}$

$h_{inlet} = \dfrac{h_c + 2.2 h_w}{3.2}$

$\Rightarrow T_{inlet} = \dfrac{T_c + 2.2 T_w}{3.2} = \dfrac{280 + 2.2(307)}{3.2}$

$= 298.76 \ kJ/kg.$ //

Note: In the question, C_p is given a constant, in reality it is not.

b) $v_c = \dfrac{RT_c}{P_c} = \dfrac{0.287 \times 280}{105} = 0.7654 \ m^3/kg.$

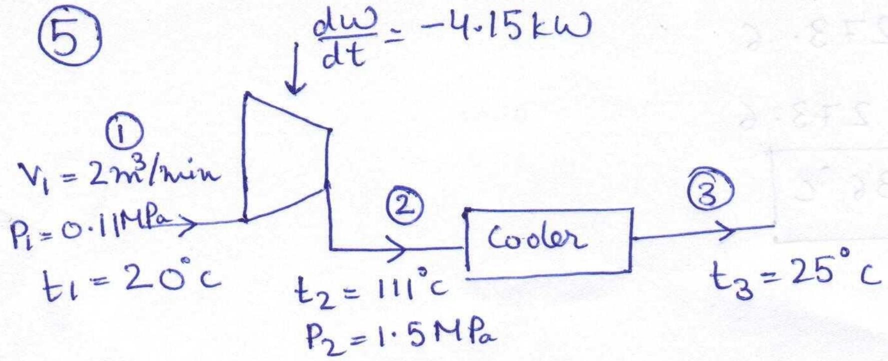
$\dot{m}_c = \dot{V}_c / v_c = 0.75 / 0.765 = 0.9799 \ kg/s.$

$\dot{m}_{in} = 3.2\dot{m}_c = 3.136 \ kg/s.$

$\dot{Q}_{gain} = \dot{m}_{in}(h_{out} - h_{in}) = 3.136 \times 1.0187\,(297.18 - 298.76)$

$= -4.93 \ kW$

(5)



$PV = mRT$

$$\dot{m} = \frac{P\dot{V}}{RT} = \frac{0.11 \times 10^6 \times 2/60}{287 \times 293} = 0.0436\ kg/s$$

Energy Conservation b/w ① & ②

(a) $$\dot{m} h_1 + \frac{dQ}{dt} = \dot{m} h_2 + \frac{dw}{dt}$$

$$\dot{Q} = \dot{m}(h_2 - h_1) + \dot{w}$$

$$= 0.0436 \times 1.005 \times (111 - 20) - 4.15$$

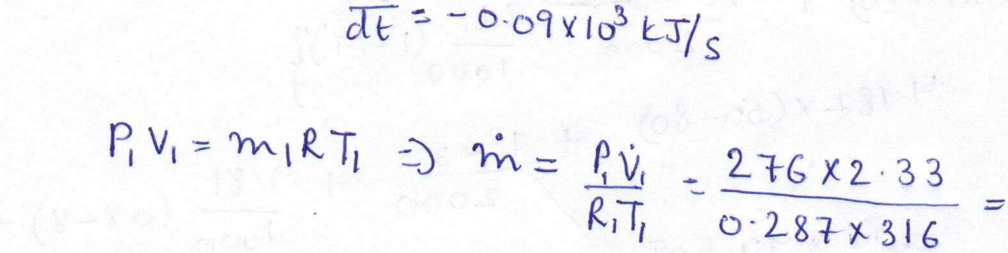
$$\boxed{\dot{Q} = -0.1622\ kW}$$ i.e. Loss by Compressor

(b) $$\dot{Q} = \dot{m} c_p (t_3 - t_2)$$

$$= 0.0436 \times 1.005 \times (25 - 111)$$

$$\boxed{\dot{Q} = -3.768\ kW}$$ to surroundings

(6)



$$P_1 V_1 = m_1 R T_1 \Rightarrow \dot{m} = \frac{P_1 \dot{V}_1}{R_1 T_1} = \frac{276 \times 2.33}{0.287 \times 316} = 7.091\ kg/s$$

$$\dot{m} h_1 + \dot{Q} = \dot{m} h_2 + \dot{w}$$

$$\dot{m}(h_1 - h_2) = \dot{w} - \dot{Q} = 1860 - (-90) = 1950\ kW$$

$$h_1 - h_2 = 275 \Rightarrow t_1 - t_2 = 275/1.005 = 273.6$$

$t_2 = t_1 - 273.6$

$= 430 - 273.6$

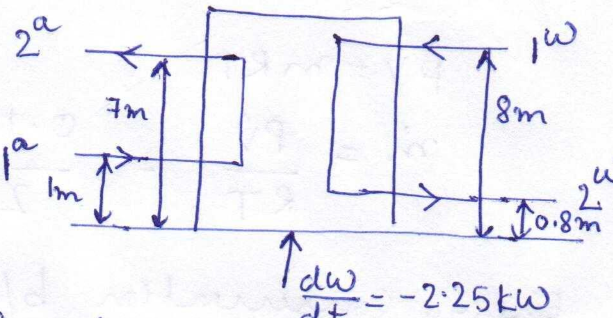
$$\boxed{t_2 = 156.36\,^\circ C}$$

(7)

Given:

@ 1^a $V_1^a = 20\,m/s$, $t_1^a = 30^\circ C$

$C_p^a = 1.005\,kJ/kg\text{-}K$



@ 2^a $V_2^a = 30\,m/s$, $t_2^a = 70^\circ C$ $\quad \dot m_1^a = \dot m_2^a = \dot m$ (say)

@ 1^w $V_1^w = 3\,m/s$, $t_1^w = 80^\circ C$

@ 2^w $V_2^w = 1\,m/s$, $t_2^w = 50^\circ C$ $\quad w_1^w = w_2^w = 1\,kg/s$ $\quad w_1 : \dot m_1$

$$\dot m_1^a\left(h_1^a + \frac{V_1^{a2}}{2} + g z_1^a\right) + \dot m_1^w\left(h_1^w + \frac{V_1^{w2}}{2} + g z_1^w\right) + \cancel{\frac{dQ}{dt}}^{\,0}$$

$$= \dot m_2^a\left(h_2^a + \frac{V_2^{a2}}{2} + g z_2^a\right) + \dot m_2^w\left(h_2^w + \frac{V_2^{w2}}{2} + g z_2^w\right) + \frac{dw}{dt}$$

$$\dot m\left((h_1^a - h_2^a) + \frac{V_1^{a2} - V_2^{a2}}{2} + g(z_1^a - z_2^a)\right)$$

$$= \left\{(h_2^w - h_1^w) + \frac{V_2^{w2} - V_1^{w2}}{2} + g(z_2^w - z_1^w)\right\} + \frac{dw}{dt}$$

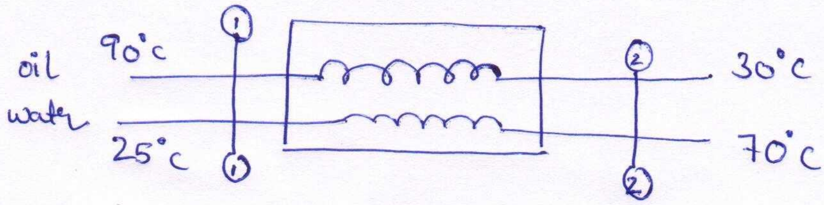
$$\dot m\left\{1.005 \times (30 - 70) + \frac{20^2 - 30^2}{2000} + \frac{9.81}{1000}(1 - 7)\right\}$$

$$= 4.187 \times (50 - 80) + \frac{1^2 - 3^2}{2000} + \frac{9.81}{1000}(0.8 - 8) - 2.25$$

$$-\dot m \times 40.509 = -127.9346$$

$$\boxed{\dot m = \frac{127.9346}{40.509} = 3.1582\,kg/s}$$

(8)



Oil : o   water : H_2O

$$h_{oil,1} = 1.68 \times 90 + 10.5 \times 10^{-4} \times 90^2 = 159.705 \text{ kJ/kg}$$

$$h_{oil,2} = 1.68 \times 30 + 10.5 \times 10^{-4} \times 36^2 = 51.395 \text{ kJ/kg}$$

$$\dot{m}_o (h_{oil,1} - h_{oil,2}) = \dot{m}_{H_2O} (h_{H_2O,2} - h_{H_2O,1})$$

$$\dot{m}_{H_2O} = \frac{\dot{m}_o (h_{oil,1} - h_{oil,2})}{h_{H_2O,2} - h_{H_2O,1}}$$

$$= \frac{2.78 \times 108.36}{4.187 (70 - 25)} \text{ kg/s}$$

$$\boxed{\dot{m} = 1.59 \text{ kg/s}}$$