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No. Kad Pengenalan/No. ISID:.....
I.C. No./ISID No.

No. Soalan:.....
Question No.

Muka surat.....
Page

Jangan tulis apa-apa di ruangan ini
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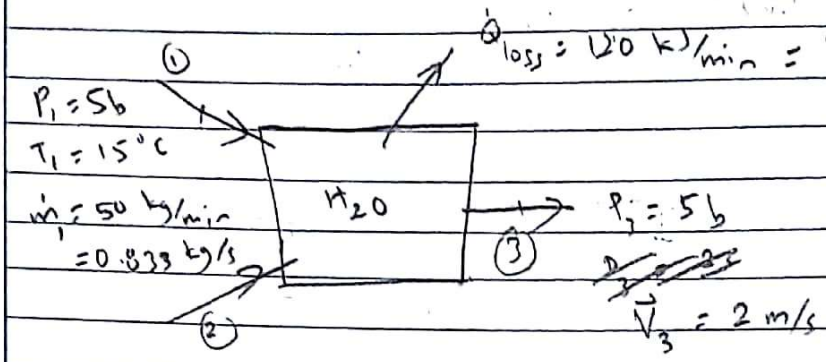
(1)



$P_2 = 5b$

$T_2 = 200°C$

$\vec{V}_2 = 120$ m/s

$D_2 = 2$ cm

(a) $T_3 = ?$

1st law:

$$\dot{Q} - \dot{W} = \sum_{out} \dot{m}(h + ke + pe) - \sum_{in} \dot{m}(h + ke + pe)$$

$$-2\text{ kW} = \dot{m}_3\left(h_3 + \frac{\vec{V}_3^2}{2000}\right) - \left[\dot{m}_1(h_1) + \dot{m}_2\left(h_2 + \frac{\vec{V}_2^2}{2000}\right)\right] \quad 1$$

$\dot{m}_1 = 0.8333$ kg/s

$\dot{m}_2 = \dfrac{\vec{V}_2 A_2}{v_2}$ $\quad \left.\begin{matrix} P_2 \\ T_2 \end{matrix}\right\} v_2 = 0.42503\ m^3/kg$ $\quad 1$

$= \dfrac{(120)(0.02^2\pi/4)}{0.42503} = 0.0887$ kg/s $\quad 4$

$\dot{m}_3 = \dot{m}_1 + \dot{m}_2 = 0.9220$ kg/s

enthalpies:

$\left.\begin{matrix} P_1 \\ T_1 \end{matrix}\right\} h_1 \triangleq h_{@T_1} = 62.982$ kJ/kg $\quad 1$

compressed liq

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No. Kad Pengenalan/No. ISID:.....
I.C. No./ISID No.

No. Soalan:..... Muka surat.....
Question No. *Page*

Jangan tulis apa-apa di ruangan ini
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P_2, T_2 } superheated : $h_2 = 2855.8$ kJ/kg

1st. law:

$$-2 = 0.922\left(h_3 + \frac{2^2}{2000}\right) - \left[0.833(62.982) + 0.0887\left(2855.8 + \frac{120^2}{2000}\right)\right]$$

$$\rightarrow h_3 = 330.16 \text{ kJ/kg}$$

T_3 from P_3, h_3 } $h_3 < h_f$ (compressed liq)

$\therefore T_3 = T_{sat}|_{h_3 = h_f}$ (interpolation)

$$\frac{\Delta T}{\Delta h} = \frac{T_3 - 75}{330.21 - 313.93} = \frac{80 - 75}{334.91 - 313.93}$$

$$\rightarrow T_3 = 78.88\,^{\circ}C$$

(ii) $d_3 = ?$

$$\dot{m}_3 = \frac{A_3 \vec{V}_3}{v_3} = \frac{\pi d_3^2}{4}\frac{\vec{V}_3}{v_3}$$

$v_3 = v_f|_{T_3}$ (compressed liq) ; interpolation!

$$\frac{\Delta v_a}{\Delta T} = \frac{v_3 - v_{f_a}}{T_3 - T_a} = \frac{v_{f_b} - v_{f_a}}{T_b - T_a}$$

$$\frac{v_3 - 0.001026}{78.88 - 75} = \frac{0.001029 - 0.001026}{80 - 75}$$

$$\rightarrow v_3 = 0.001028 \text{ m}^3/\text{kg}$$

$$\frac{55.323}{60}\ \frac{\text{kg}}{\text{s}} = \frac{\pi d_3^2}{4}\frac{2}{0.001028} \rightarrow d_3 = 0.0246 \text{ m} = 2.46 \text{ cm}$$

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UNIVERSITI TEKNOLOGI MALAYSIA

No. Kad Pengenalan/No. ISID:.....
I.C. No./ISID No.

No. Soalan:.....
Question No.

Muka surat.....
Page

Jangan tulis apa-apa di ruangan ini
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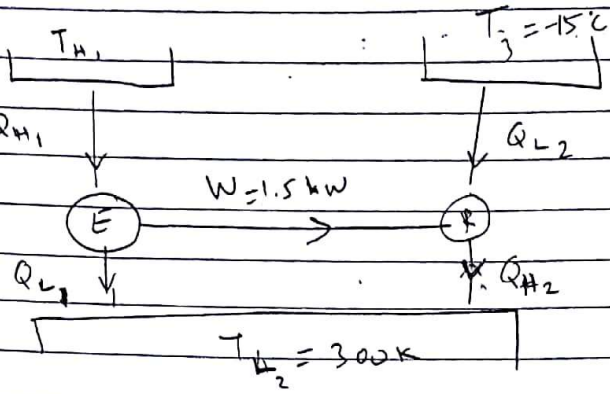
Q2.



$\eta_E = \eta_{Carnot} = 60\%$

(i) $\eta_{Carnot} = 0.6 = \dfrac{T_{H_1} - T_{L_2}}{T_{H_1}} = 1 - \dfrac{T_{L_2}}{T_{H_1}}$

$= 1 - \dfrac{300}{T_{H_1}}$ 4

$\therefore T_{H_1} = 750\ K$

$\eta = 0.6 = \dfrac{W}{Q_{H_1}} = \dfrac{1.5\ kW}{Q_{H_1}}$ 3

$\therefore Q_{H_1} = 2.5\ kW$

$Q_{L_1} = Q_{H_1} - W = 1\ kW$ 3

(ii) Carnot refrigerator

$COP_R = \dfrac{T_L}{T_H - T_L} = \dfrac{T_3}{T_{L_2} - T_3}$

$= \dfrac{(-15 + 273)}{300 - (-15 + 273)}$ 4

$= 6.14$

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No. Kad Pengenalan/No. ISID:.....
I.C. No./ISID No.

No. Soalan:..... Muka surat.....
Question No. *Page*

Jangan tulis apa-apa di ruangan ini
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$$COP_R = 6.4 = \frac{\dot{Q}_{L2}}{\dot{W}} = \frac{\dot{Q}_{L2}}{1.5\,kW}$$

3

$$\therefore \dot{Q}_{L2} = 9.21\ kW_{\#}$$

$$\dot{Q}_{H2} = \dot{Q}_{L2} + \dot{W} = 10.71\ kW_{\#}$$

3

20

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No. Kad Pengenalan/No. ISID:.....
I.C. No./ISID No.

No. Soalan:..... Muka surat.....
Question No. Page

Jangan tulis apa-apa di ruangan ini
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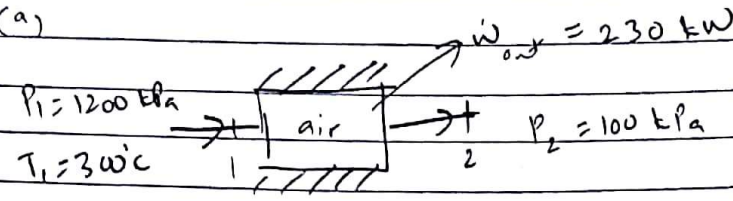
G3 (a)



$\dot{m} = 1$ kg/s

validity of device.

Assuming isentropic ($W_{max,out}$)

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$\frac{T_2}{573} = \left(\frac{100}{1200}\right)^{\left(\frac{0.4}{1.4}\right)}$$

$\rightarrow T_2 = 281.72$ K

4

W_{max} by 1st Law

$\dot{Q} - \dot{W} = \dot{m}(\Delta h + \Delta ke + \Delta pe)$

$-\dot{W}_{max} = 1\,(C_p\,(T_2 - T_1))$

$= 1.005\,(281.72 - 573)$

$\dot{W}_{max} = 292.74$ kW

4

$\dot{W}_{out} < \dot{W}_{max}$ (valid!)

2

- different approach: check isen

1st Law: $\dot{Q} - \dot{W} = \dot{m}(\Delta h + \Delta ke + \Delta pe)$

-230 kW $= 1$ kg/s $C_p\,(T_2 - T_1)$

$\therefore T_2 = 344.14$ K

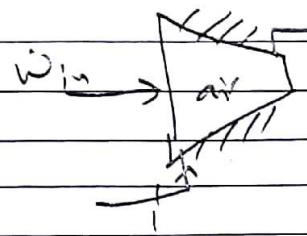
$$\frac{dS_{cv}}{dt} = \sum \frac{\dot{Q}}{T} + \dot{m}(s_1 - s_2) + \dot{s}_{gen}$$

$$0 = 1\left(c_p \ln \frac{T_1}{T_2} - R \ln \frac{P_1}{P_2}\right) + \dot{s}_{gen}$$

$$= 1.005 \ln\left(\frac{573}{344.14}\right) - 0.287 \ln\left(\frac{1200}{100}\right) + \dot{s}_{gen}$$

$$\dot{s}_{gen} = 0.2008 \ \frac{kW}{K} > 0 \quad (\text{valid!})$$

(b)



$\eta_c = 0.75$

$T_1 = 30^\circ C$

$P_1 = 1$ b

(i) $T_{2a} = ?$

$$\frac{T_{2s}}{T_1} = \left(\frac{P_2}{P_1}\right)^{\left(\frac{k-1}{k}\right)}$$

$$T_{2s} = 303 \left(\frac{9}{1}\right)^{\left(\frac{0.4}{1.4}\right)} = 567.6 \ K$$

$$\eta_c = 0.75 = \frac{T_{2s} - T_1}{T_{2a} - T_1} = \frac{567.6 - 303}{T_{2a} - 303}$$

$$\therefore T_{2a} = 655.8 \ K \ \#$$

(ii) $\frac{dS_{cv}}{dt} = \sum \frac{\dot{Q}}{T} + \dot{m}(s_1 - s_2) + \dot{s}_{gen}$

$$s_{gen} = s_2 - s_1 = c_p \ln \frac{T_{2a}}{T_1} - R \ln \frac{P_2}{P_1}$$

$$= 1.005 \ln\left(\frac{655.8}{303}\right) - 0.287 \ln(9)$$

$$= 0.1454 \ \frac{kJ}{kg.K} \ \#$$

2

3

5

10