higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES N6

22 April 2021

This marking guideline consists of 10 pages.

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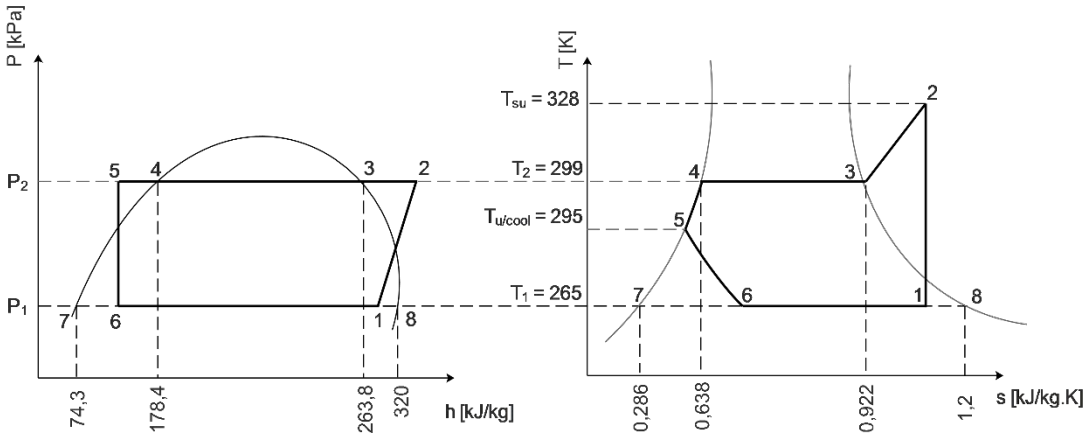
QUESTION 1

1.1



$$s_2 = s_3 + C_p \ln\left(\frac{T_{su}}{T_2}\right) \checkmark$$

$$= 0{,}922 + 2{,}6 \ln\left(\frac{328}{299}\right) \checkmark$$

$$= 1{,}163 \text{ kJ/kg. K} \checkmark \quad (3)$$

1.2 $$s_1 = s_7 + x_1(s_8 - s_7)$$

$$x_1 = \frac{s_1 - s_7}{s_8 - s_7}$$

$$= \frac{1{,}163 - 0{,}286}{1{,}2 - 0{,}286} \checkmark$$

$$= 0{,}96 \checkmark \quad (2)$$

1.3 $$h_1 = h_7 + x_1(h_8 - h_7) \checkmark$$

$$= 74{,}3 + 0{,}96(320 - 74{,}3) \checkmark$$

$$= 310{,}172 \text{ kJ/kg} \checkmark \quad (3)$$

1.4 $$h_2 = h_3 + C_p(T_{su} - T_2) \checkmark$$

$$= 263{,}8 + 2{,}6(328 - 299) \checkmark$$

$$= 339{,}2 \text{ kJ/kg} \checkmark \quad (3)$$

1.5 $$h_5 = h_4 - C_p\left(T_2 - T_{u/cool}\right)$$

$$= 178{,}4 - 5{,}4(299 - 295) \checkmark$$

$$= 156{,}8 \text{ kJ/kg} \checkmark \quad (2)$$

1.6 $RE = h_1 - h_6$

$= 310{,}172 - 156{,}8$✓

$= 153{,}372\ \text{kJ/kg}$✓ (2)

1.7 $W_d = h_2 - h_1$

$= 339{,}2 - 310{,}172$✓

$= 29{,}028\ \text{kJ/kg}$✓ (2)

1.8 $COP = \dfrac{RE}{W_d}$

$= \dfrac{153{,}372}{29{,}028}$

$= 5{,}284$✓ (1)

1.9 $P_{motor} = \dot{m}_r(h_2 - h_1) \times \dfrac{1}{\eta_{mech.}}$

$= \left(\dfrac{17}{60}\right) \times (29{,}028) \times \dfrac{1}{0{,}85}$✓

$= 9{,}676\ \text{kW}$✓ (2)
[20]

QUESTION 2

2.1 $At\ 29\ ℃: h_{fw1} = 121\ \text{kJ/kg}$

$At\ 86\ ℃: h_{fw2} = 360\ \text{kJ/kg}$

$Q_{econ.} = \dfrac{m_s}{m_f}\left(h_{fw2} - h_{fw1}\right)$

$\dfrac{m_s}{m_f} = \dfrac{Q_{econ.}}{h_{fw2} - h_{fw1}}$

$= \dfrac{2\ 188}{360_{(86\ ℃)} - 121_{(29\ ℃)}}$✓

$= 9{,}155\ \text{kg/kg}$✓ (2)

2.2 At 3 800 kPa: $h_g = 2\,801$ kJ/kg and $t_s = 247{,}3$ ℃

$h_{su} = h_g + C_p(t_{su} - t_s)$✓

$= 2\,801_{3\,800\text{ kPa}} + 3{,}2(298 - 247{,}3_{3\,800\text{ kPa}})$✓

$= 2\,963{,}24$ kJ/kg✓ (3)

2.3 At 3 800 kPa: $h_f = 1\,073$ kJ/kg and $h_{fg} = 1\,728$ kJ/kg

$$\eta_{evap.} = \frac{m_s(h_f + xh_{fg} - h_{fw2})}{m_f \times CV}$$✓

$$= \frac{9{,}155[1\,073_{(3\,800\text{ kPa})} + 0{,}986 \times 1\,728_{(3\,800\text{ kPa})} - 360_{(86\text{ ℃})}]}{1 \times 32\,000}$$✓

$= 69{,}143\%$✓ (3)

2.4 $$\eta_{th} = \frac{m_s(h_{su} - h_{fw1})}{m_f \times CV}$$✓

$$= \frac{9{,}155(2\,963{,}24 - 121_{(29\text{ ℃})})}{1 \times 32\,000} \times 100$$✓

$= 81{,}315\%$✓ (3)

2.5 $$\eta_{air-heater} = \frac{m_a C_{pa} \Delta t_a}{CV} \times 100$$✓

$$= \frac{18 \times 1{,}005(137 - 26)}{32\,000} \times 100$$✓

$= 6{,}275\%$✓ (3)

2.6 $$\eta_{chimney} = \frac{m_g C_{pg} \Delta t_g}{CV} \times 100$$✓

$$= \frac{(18 + 1) \times 1{,}045(177 - 26)}{32\,000} \times 100$$✓

$= 9{,}369\%$✓ (3)

2.7 $$\eta_{th} = \frac{m_s(h_f + xh_{fg} - h_{fw1})}{m_f \times CV} \times 100$$✓

$$= \frac{9{,}155(1\,073_{(3\,800\text{ kPa})} + 0{,}986 \times 1\,728_{(3\,800\text{ kPa})} - 121_{(29\text{ ℃})})}{1 \times 32\,000} \times 100$$✓

$= 75{,}981\%$✓ (3)

[20]

QUESTION 3

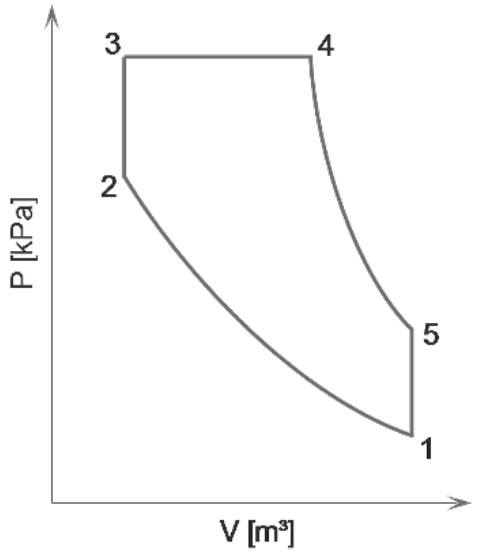
3.1 $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n_c-1}$ ✓

$(n_c - 1)\ln\left(\frac{V_1}{V_2}\right) = \ln\left(\frac{T_2}{T_1}\right)$

$n_c = 1 + \frac{\ln\left(\frac{T_2}{T_1}\right)}{\ln\left(\frac{V_1}{V_2}\right)}$ ✓

$= 1 + \frac{ln2,75}{ln18}$ ✓

$= 1,35$ ✓



(4)

3.2 $\frac{P_5}{T_5} = \frac{P_1}{T_1}$

$T_1 = \frac{P_1}{P_5} \times T_5$

$= \left(\frac{1}{6,25}\right) \times 1\,824$ ✓

$T_1 = 291,84\ \text{K}$ ✓

$T_2 = 2,75T_1$

$= 2,75 \times 291,84$ ✓

$T_2 = 802,56\ \text{K}$ ✓

$Q_{2-3} = mC_v(T_3 - T_2)$

$T_3 = \frac{Q_{2-3}}{mC_v} + T_2$ ✓

$= \frac{314,96}{1 \times 0,72} + 802,56$ ✓

$T_3 = 1\,240,004\ \text{K}$ ✓

$V_3 = V_2$ ✓ $= V_1\left(\frac{T_1}{T_2}\right)^{\frac{1}{n_c-1}}$

$= 4\,800\left(\frac{1}{2,75}\right)^{\frac{1}{0,35}}$ ✓

$V_3 = V_2 = 266{,}689\ \text{cm}^3$✓

$V_4 = V_3 + 0{,}1V_s$

$= V_3 + 0{,}1(V_1 - V_2)$✓

$= 266{,}89 + 0{,}1(4\,800 - 266{,}89)$✓

$V_4 = 720{,}02\ \text{cm}^3$✓

$T_4 = T_5\left(\frac{V_5}{V_4}\right)^{n_e-1}$ ✓

$= 1\,824\left(\frac{4\,800}{720{,}02}\right)^{0{,}32}$ ✓

$T_4 = 3\,347{,}124\ \text{K}$✓

OR

$T_4 = \frac{V_4 T_3}{V_3}$ ✓

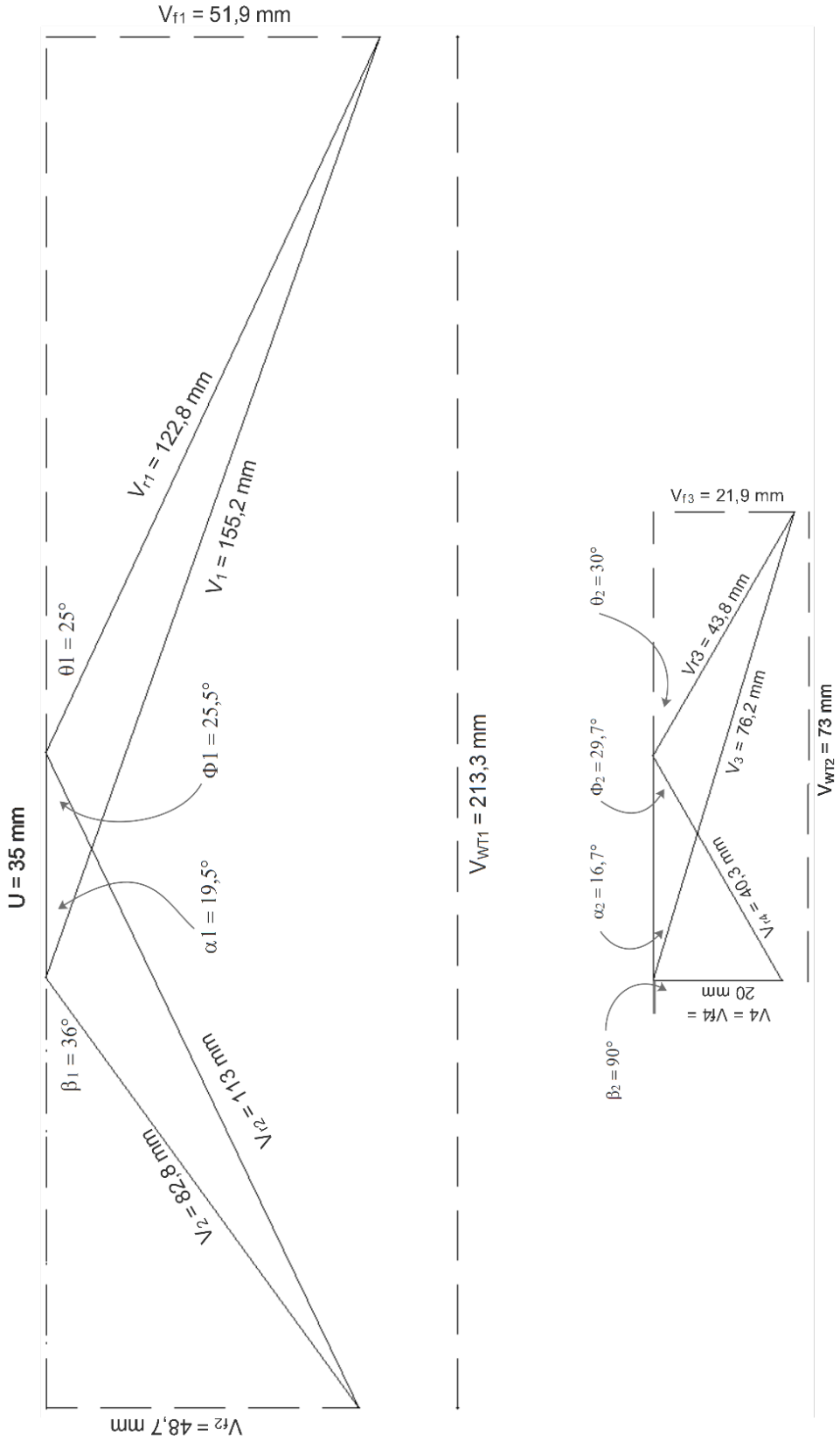
$= \frac{720{,}02 \times 1\,240{,}004}{266{,}689}$ ✓

$T_4 = 3\,347{,}823\ \text{K}$✓ (16)

[20]

QUESTION 4

4.1



(½ mark per correct length or angle to a maximum of 5 marks per stage)
(Allow a tolerance of ±2 mm for line segments and ±1° for magnitude of angles) (10)

4.2 4.2.1 $\alpha_1 = 19{,}5°$✓ (1)

4.2.2 $F_{ax} = \dot{m}\left[\left(V_{f1} - V_{f2}\right) + \left(V_{f3} - V_{f4}\right)\right]$✓

$= 50[(51{,}9 - 48{,}7) \times 3 + (21{,}9 - 20) \times 3]$✓

$= 765$ N✓ (3)

4.2.3 $\eta = \frac{2UV_{WT}}{V_1^2} \times 100$✓

$= \frac{2 \times 105 \times (213{,}3 + 73) \times 3}{(155{,}2 \times 3)^2} \times 100$✓

$= 83{,}202\%$✓ (3)

4.2.4 $P = \dot{m}U(V_{WT})$✓

$= 50 \times 105 \times (213{,}3 + 73) \times 3$✓

$= 4{,}509$ MW✓ (3)
[20]

QUESTION 5

5.1 $T_1 - T_c = 126$

$T_c = T_1 - 126$

$= 756 - 126$

$= 630$ K✓ (1)

5.2 $\frac{T_c}{T_1} = \frac{2}{\gamma + 1}$

$\gamma = \frac{2T_1}{T_c} - 1$

$= \frac{2 \times 756}{630} - 1$✓

$= 1{,}4$✓ (2)

5.3 $$P_c = P_1\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$$

$$= 3\,200\left(\frac{2}{2{,}4}\right)^{\frac{1{,}4}{0{,}4}} \checkmark$$

$$= 1\,690{,}502\ \text{kPa} \checkmark \quad (2)$$

5.4 $$C_c = \sqrt{2\,000\ C_p\ (T_1 - T_c)}$$

$$C_p = \frac{C_c^2}{2\,000\ (T_1 - T_c)}$$

$$= \frac{504^2}{2\,000 \times 126} \checkmark$$

$$= 1{,}008\ \text{kJ/kg.K} \checkmark \quad (2)$$

5.5 $$\gamma = \frac{C_p}{C_v}$$

$$C_v = \frac{C_p}{\gamma}$$

$$= \frac{1{,}008}{1{,}4} \checkmark$$

$$= 0{,}72\ \text{kJ/kg.K} \checkmark \quad (2)$$

5.6 $$R = C_p - C_v$$

$$= 1{,}008 - 0{,}72 \checkmark$$

$$= 0{,}288\ \text{kJ/kg.K} \checkmark \quad (2)$$

5.7 $$V_c = \frac{RT_c}{P_c}$$

$$= \frac{0{,}288 \times 630}{1\,690{,}502} \checkmark$$

$$= 0{,}107\ \text{m}^3/\text{kg} \checkmark \quad (2)$$

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5.8 5.8.1

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

$$= 756\left(\frac{500}{3\,200}\right)^{\frac{0,4}{1,4}} \checkmark$$

$$= 444,82\ \text{K} \checkmark \quad (2)$$

5.8.2 $C_2 = C_c \times Ma$

$$= 504 \times 1,54$$

$$= 776,16\ \text{m/s} \checkmark \quad (1)$$

5.8.3 $$C_2 = \sqrt{2\,000\ C_p\ (T_1 - T_2)}$$

$$T_2 = T_1 - \frac{C_2^2}{2\,000\ C_p}$$

$$= 756 - \frac{776,16^2}{2\,000 \times 1,008} \checkmark$$

$$= 457,178\ \text{K} \checkmark \quad (2)$$

5.9 $$\eta_{div} = \frac{T_c - T_2}{T_c - T_2'}$$

$$= \frac{630 - 457,178}{630 - 444,82} \times 100 \checkmark$$

$$= 93,326\% \checkmark \quad (2)$$

[20]

TOTAL: 100

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