higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES N6

18 November 2020

This marking guideline consists of 10 pages.

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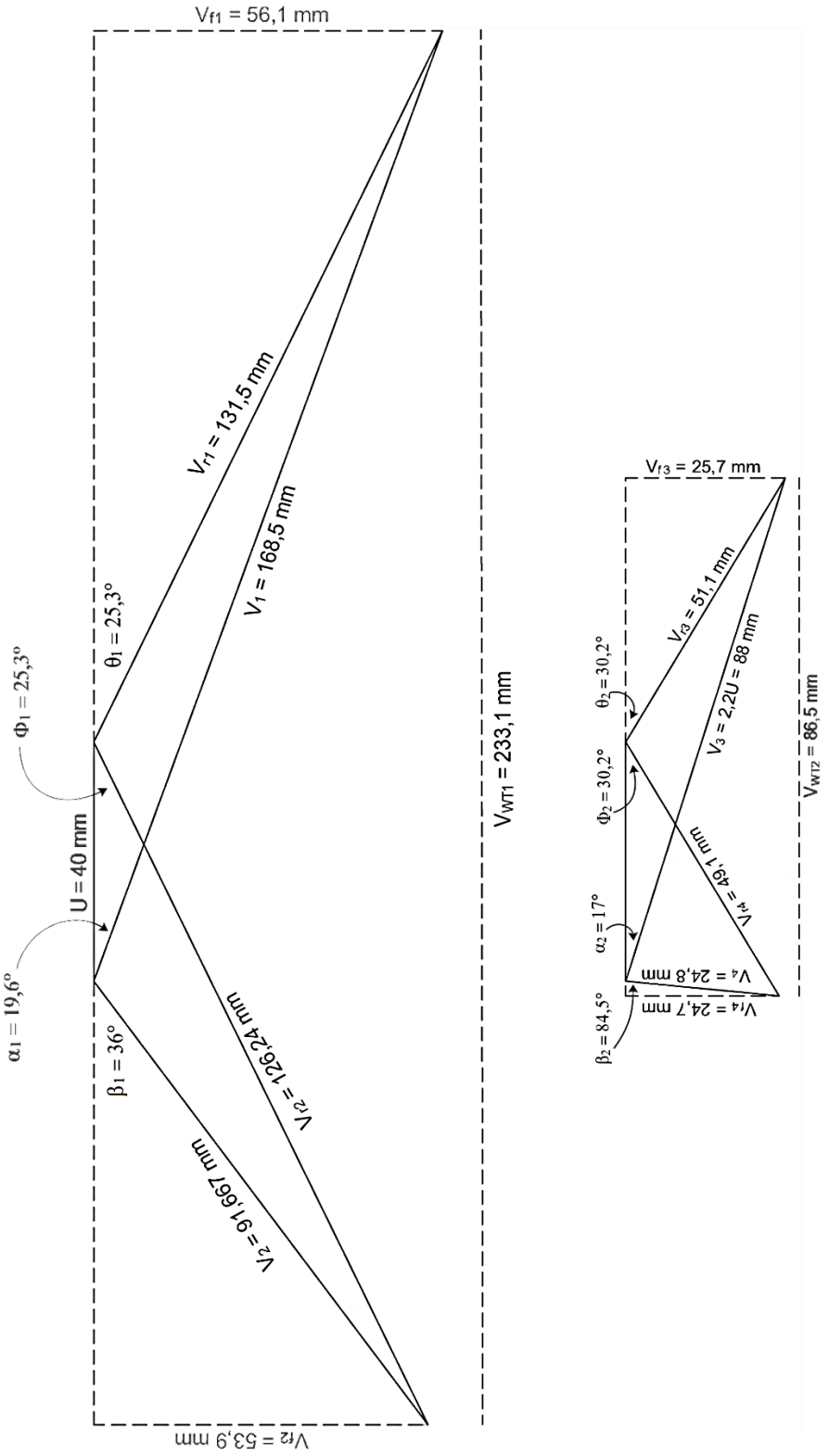
QUESTION 1

1.1



Award 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)

1.2 $Scale = \frac{V_{[m/s]}}{V_{[mm]}}$

$= \frac{526}{131,5}$

$= 4:1$✓ (1)

1.3 1.3.1 $\beta_2 = 84,5°$✓ (1)

1.3.2 $\alpha_1 = 19,6°$✓ (1)

1.3.3 $V_2 = 91,667 \times 4$

$= 366,668 \text{ m/s}$✓ (1)

1.3.4 $F_{ax} = \dot{m}\left[\left(V_{f1} - V_{f2}\right) + \left(V_{f3} - V_{f4}\right)\right]$

$= 62[(56,1 - 53,9) \times 4$✓ $+ (25,7 - 24,7) \times 4]$✓

$= 793,6 \text{ N}$✓ (3)

1.3.5 $P = \dot{m}UV_{WT}$

$= 62 \times 160 \times [(233,1 \times 4)$✓$+ (86,5 \times 4)]$✓

$= 12,682 \text{ MW}$✓ (3)
[20]

QUESTION 2

2.1 $C_c = \sqrt{2\,000C_p(T_1 - T_c)}$

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

$= 1\,020 - \frac{584,55^2}{2\,000 \times 1,005}$✓

$= 850 \text{ K}$✓ (2)

2.2 $\frac{T_c}{T_1} = \frac{2}{\gamma + 1}$

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

$= \frac{2 \times 1\,020}{850} - 1$✓

$= 1{,}4$✓

OR

$C_c = \sqrt{1\,000\,\gamma R T_c}$

$\gamma = \frac{C_c^2}{1\,000 R T_c}$

$= \frac{584{,}55^2}{1\,000 \times 0{,}287 \times 850}$✓

$= 1{,}4$✓ (2)

2.3 $P_c = P_1 \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma - 1}}$

$= 653 \left(\frac{2}{2{,}4}\right)^{\frac{1{,}4}{0{,}4}}$✓

$= 344{,}968\ \text{kPa}$✓ (2)

2.4 2.4.1 $\frac{T_2'}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma - 1}{\gamma}}$

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

$= 653 \left(\frac{750}{1\,020}\right)^{\frac{1{,}4}{0{,}4}}$✓

$= 222{,}601\ \text{kPa}$✓

2.4.2 $$\eta = \frac{T_1 - T_2}{T_1 - T_2'}$$

$$T_2 = T_1 - \eta(T_1 - T_2)$$

$$= 1\,020 - 0{,}9(1\,020 - 750)\checkmark$$

$$= 777\text{ K}\checkmark$$

2.4.3 $$C_2 = \sqrt{2\,000 C_p (T_1 - T_2)}$$

$$= \sqrt{2\,000 \times 1{,}005(1\,020 - 777)}\checkmark$$

$$= 698{,}878\text{ m/s}\checkmark$$

2.4.4 $$V_2 = \frac{RT_2}{P_2}$$

$$= \frac{0{,}287 \times 777}{222{,}601}\checkmark$$

$$= 1{,}002\text{ m}^3/\text{kg}\checkmark$$

2.4.5 $$A_2 = \frac{\dot{m}V_2}{C_2}$$

$$= \frac{\left(\frac{240}{60}\right) \times 1{,}002}{698{,}878} \times 10^6\checkmark$$

$$= 5\,734{,}907\text{ mm}^2\checkmark$$

2.4.6 $$D_2 = \sqrt{\frac{4 \times A_2}{\pi}}$$

$$= \sqrt{\frac{4 \times 5\,734{,}907}{\pi}}\checkmark$$

$$= 85{,}451\text{ mm}\checkmark$$

(6 × 2) (12)

2.5 $\dot{V}_c = \frac{\dot{m}RT_c}{P_c}$

$= \frac{\left(\frac{240}{60}\right) \times 0{,}287 \times 850}{344{,}968}$ ✓

$= 2{,}829\ \text{m}^3/\text{s}$ ✓ (2)

[20]

QUESTION 3

3.1 3.1.1 At 59 °C: $h_{fw1} = 247$ kJ/kg
At 104,8 °C: $h_{fw2} = 439$ kJ/kg

$h_{econ.} = h_{fw2} - h_{fw1}$

$= 439_{(104{,}8\,°C)} - 247_{(59\,°C)}$ ✓

$= 192$ kJ/kg steam ✓ (2)

3.1.2 At 2 000 kPa: $h_f = 908$ kJ/kg and $h_{fg} = 1\,889$ kJ/kg

$h_{evap.} = h_f + xh_{fg} - h_{fw2}$

$= 908_{(2\,000\,\text{kPa})} + \left(0{,}92 \times 1\,889_{(2\,000\,\text{kPa})}\right) - 439_{(104{,}8\,°C)}$ ✓

$= 2\,206{,}88$ kJ/kg steam ✓ (2)

3.1.3 At 2 000 kPa and 250 °C: $h_{su} = 2\,904$ kJ/kg

$h_{s/heater} = h_{su} - \left[h_f + xh_{fg}\right]$

$= 2\,904_{(2000\,\text{kPa}/250\,°C)}$ ✓ $- \left[908_{(2000\,\text{kPa})} + 0{,}92 \times 1\,889_{(2000\,\text{kPa})}\right]$ ✓

$= 258{,}12$ kJ/kg steam ✓ (3)

3.1.4 At 100 kPa and 200 °C: $h_{su} = 2\,876$ kJ/kg

$\dot{Q_{moisture}} = m_{moisture}[h_{su} - c_w\Delta t] \times \dot{m_{fuel}}$

$= 0{,}55\left[2\,876_{(100\,\text{kPa}/200\,°C)}\right.$ ✓ $\left. - 4{,}2(20)\right] \times \left(\frac{2\,940}{60}\right)$ ✓

$= 72\,818{,}9$ kJ/min ✓ (3)

3.1.5 $\dot{Q_{dry\ flue}} = (m_{dry\ flue} - m_{moisture})C_{pg}\Delta t_g \times \dot{m_{fuel}}$✓

$= (16 - 0{,}55) \times 1{,}05 \times (200 - 20) \times \left(\frac{2\,940}{60}\right)$✓

$= 143\,082{,}45$ kJ/min✓ (3)

3.2

$\dot{Q_{in}}$ [kJ/min]	$\dot{Q_{out}}$ [kJ/min]	%
$31\,000 \times \frac{2\,940}{60} = 1\,519\,000$	$Econ. = \frac{28\,000}{60} \times 192 = 89\,600$	5,899✓
	$Evap. = \frac{28\,000}{60} \times 2\,206{,}88 = 1\,029\,877{,}333$	67,8✓
	$S_{heater} = \frac{28\,000}{60} \times 258{,}12 = 120\,456$	7,93✓
	$Q_{lost} = 45\,570$✓	3
	$Flue_{wet} = 72\,818{,}9$	4,794✓
	$Flue_{dry} = 143\,082{,}45$	9,42✓
	$Q_{radiation} = 1\,519\,000 - 1\,501\,404{,}684 = 17\,595{,}316$	1,158✓
1 519 000	1 519 000	100

(7)
[20]

QUESTION 4

4.1 4.1.1 $BP = \frac{2\pi NT}{60}$

$= \frac{2\pi N(FgR)}{60}$✓

$= \frac{2\pi \times 2\,900 \times (17{,}412 \times 9{,}81 \times 1{,}1)}{60 \times 10^3}$✓

$= 57{,}061$ kW✓ (3)

4.1.2 $\eta_{mech.} = \frac{BP}{IP} = \frac{3}{4}$

$IP = BP \times \frac{1}{\eta_{mech.}}$

$= 57{,}061 \times \frac{4}{3}$✓

$= 76{,}081$ kW✓ (2)

4.1.3 $$BSFC = \frac{\dot{m_{f/h}}}{BP}$$

$$= \frac{(0{,}3 \times 60)}{57{,}061}\checkmark$$

$$= 0{,}315 \text{ kg/kW.h}\checkmark$$ (2)

4.1.4 $$\dot{m}_g = (m_a + 1)\dot{m}_f$$

$$m_a = \frac{\dot{m}_g}{\dot{m}_f} - 1$$

$$= \frac{\left(\frac{290}{60}\right)}{0{,}3} - 1\checkmark$$

$$= 15{,}111 \text{ kg air / kg fuel}\checkmark$$ (2)

4.1.5 $$Q_g = \dot{m}_g C_{pg} \Delta t_g$$

$$= \left(\frac{290}{60}\right) \times 1{,}045 \times 530\checkmark$$

$$= 2\,676{,}942 \text{ kJ / min}\checkmark$$ (2)

4.1.6 $$\eta_{ind\ th.} = \frac{IP}{\dot{m_{f/s}} \times CV} \times 100$$

$$= \frac{76{,}081}{\left(\frac{0{,}3}{60}\right) \times 43\,000} \times 100\checkmark$$

$$= 35{,}387\%\checkmark$$ (2)

4.2

$\dot{Q_{in}}$ [kJ/min]	$\dot{Q_{out}}$ [kJ/min]	%
$43\,000 \times 0{,}3 = 12\,900$	$BP = 57{,}061 \times 60 = 3\,423{,}66\checkmark$	$26{,}54\checkmark$
	$Cooling\ water = 14 \times 52 = 3\,057{,}6\checkmark$	$23{,}702\checkmark$
	$Exhaust\ gas = 2\,676{,}942$	$20{,}751\checkmark$
	$Radiation = 12\,900 - 9\,158{,}202$ $= 3\,741{,}798\checkmark$	$29{,}006\checkmark$
12 900	12 900	100

(7)
[20]

QUESTION 5

5.1

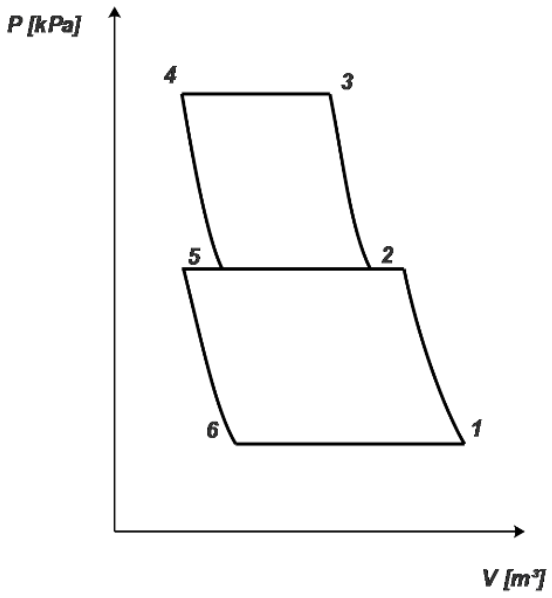
$$\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \frac{T_2'}{T_1}$$

$$\frac{n-1}{n}\ln\left(\frac{P_2}{P_1}\right) = \ln\left(\frac{T_2'}{T_1}\right) \checkmark$$

$$\frac{n-1}{n}\ln(4) = \ln\left(\frac{415}{297}\right) \checkmark$$

$$n = \frac{\ln(4)}{\ln(4) - \ln\left(\frac{415}{297}\right)} \checkmark$$

$$n = 1{,}32 \checkmark$$



(4)

5.2

$$P_{compr.} = \frac{n}{n-1}\dot{m}RT_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] + \frac{n}{n-1}\dot{m}RT_2\left[\left(\frac{P_3}{P_2}\right)^{\frac{n-1}{n}} - 1\right] \checkmark$$

$$= \frac{1{,}32}{0{,}32} \times \left(\frac{14{,}6}{60}\right) \times 0{,}288 \times 297\left[(4)^{\frac{0{,}32}{1{,}32}} - 1\right] \checkmark + \frac{1{,}32}{0{,}32} \times \left(\frac{14{,}6}{60}\right) \times 0{,}288 \times 332\left[(3{,}5)^{\frac{0{,}32}{1{,}32}} - 1\right] \checkmark$$

$$= 68{,}353 \text{ kW} \checkmark$$

(4)

5.3 5.3.1

$$P_1V_{e1} = \dot{m}RT_1$$

$$V_{e1} = \frac{\dot{m}RT_1}{P_1} \times \frac{1}{N} \checkmark$$

$$= \frac{14{,}6 \times 0{,}288 \times 297}{98} \times \frac{1}{310} \checkmark$$

$$= 0{,}0411 \text{ m}^3/\text{cycle} \checkmark$$

(3)

5.3.2

$$V_{s1} = \frac{\pi}{4} \times D_1^2 \times L_1$$

$$= \frac{\pi}{4} \times (0{,}36)^2 \times 0{,}45 \checkmark$$

$$= 0{,}046 \text{ m}^3/\text{cycle} \checkmark$$

(2)

5.3.3 $$\eta_{vol1} = \frac{V_{e1}}{V_{s1}} \times 100$$

$$= \frac{0,041}{0,046} \times 100 \checkmark$$

$$= 89,13\% \checkmark$$ (2)

5.4 5.4.1 $$V_{e2} = \frac{\dot{m}RT_2}{P_2} \times \frac{1}{N}$$

$$= \frac{14,6 \times 0,288 \times 332}{(4 \times 98)} \checkmark \times \frac{1}{310} \checkmark$$

$$= 0,0115 \text{ m}^3/\text{cycle} \checkmark$$ (3)

5.4.2 $$\eta_{vol2} = \frac{Ve_2}{V_{s2}}$$

$$V_{s2} = \frac{V_{e2}}{\eta_{vol2}}$$

$$= \frac{0,0115}{0,8913} \checkmark$$

$$= 0,0129 \text{ m}^3/\text{cycle} \checkmark$$ (2)

[20]

TOTAL: 100

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