



**higher education  
& training**

Department:  
Higher Education and Training  
**REPUBLIC OF SOUTH AFRICA**

# **MARKING GUIDELINE**

**NATIONAL CERTIFICATE**

**APRIL EXAMINATION**

**POWER MACHINES N6**

**31 March 2016**

**This marking guideline consists of 11 pages.**

**QUESTION 1**

$$\begin{aligned}
 1.1 \quad P_2 &= \sqrt{P_1 \cdot P_3} \\
 &= \sqrt{104 \times 800} \\
 &= 288,44 \text{ kPa}
 \end{aligned} \tag{3}$$

$$\begin{aligned}
 1.2 \quad V_1 &= V_{e1}/N = 0,4 \times 60/550 = 0,04364 \text{ m}^3 \\
 m &= \frac{P_1 V_1}{RT_1} = \frac{104 \times 0,04364}{0,287 \times 292} = 0,05416 \text{ kg} \\
 V_{2'} &= \frac{mRT_{2'}}{P_2} = \frac{0,05416 \times 0,287 \times 292}{288,44} = 0,01574 \text{ m}^3
 \end{aligned} \tag{6}$$

$$\begin{aligned}
 1.3 \quad L_2 &= D_2 \\
 V_{s2'} &= V_{2'} = \frac{\pi (D_2)^2 \cdot D_2}{4} \\
 0,01574 &= \frac{\pi (D_2)^3}{4} \\
 \therefore L_2 = D_2 &= 271,63 \text{ mm}
 \end{aligned} \tag{4}$$

$$\begin{aligned}
 1.4 \quad P &= \frac{2n}{n-1} P_1 V_1 \left[ \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right] \\
 &= \frac{2 \times 1,3}{0,3} \times 104 \times 0,4 \left[ \left( \frac{288,44}{104} \right)^{\frac{0,3}{1,3}} - 1 \right] \\
 &= 95,69 \text{ kW}
 \end{aligned} \tag{4}$$

$$\begin{aligned}
 P_{req} &= \frac{P_{act}}{\eta} \\
 &= \frac{95,69}{0,88} \\
 &= 108,74 \text{ kW}
 \end{aligned} \tag{7}$$

**[20]**

**QUESTION 2**

- 2.1 At 44,8 °C :  $h_1 = 188 \text{ kJ/kg}$   
 At 93,5 °C :  $h_2 = 392 \text{ kJ/kg}$   
 At 1 500 kPa & 350 °C :  $h_4 = 3 148 \text{ kJ/kg}$

$$\begin{aligned} \therefore \eta_{plant} &= \frac{m_s(h_4 - h_1)}{m_f \times H_v} \times \frac{100}{1} \\ &= \frac{5400(3148 - 188)}{600 \times 32\,000} \times \frac{100}{1} \\ &= 83,25\% \end{aligned} \quad (3)$$

$$\begin{aligned} 2.2 \quad EE &= \frac{m_s(h_4 - h_1)}{m_f \times 2257} \\ &= \frac{5\,400(3148 - 188)}{600 \times 2\,257} \\ &= 11,803 \text{ kg..steam/kg..fuel} \end{aligned} \quad (2)$$

$$\begin{aligned} 2.3 \quad Q_{ECON} &= \frac{m_s(h_2 - h_1)}{m_f} \\ &= \frac{5\,400(392 - 188)}{600} \\ &= 1836 \text{ kJ / kg} \end{aligned} \quad (2)$$

- 2.4 At 1 500 kPa:  $h_f = 845 \text{ kJ/kg}$  and  $h_{fg} = 1\,945 \text{ kJ/kg}$

$$\begin{aligned} h_3 &= hf + xh_{fg} \\ &= 845 + (0,9 \times 1945) \\ &= 2\,595,5 \text{ kJ/kg} \\ Q_{EVAP} &= \frac{m_s(h_3 - h_2)}{m_f} \\ &= \frac{5\,400(2\,595,5 - 392)}{600} \\ &= 19\,831,5 \text{ kJ / kg} \end{aligned} \quad (3)$$

$$\begin{aligned} 2.5 \quad Q_{SUPER} &= \frac{m_s(h_4 - h_3)}{m_f} \\ &= \frac{5\,400(3\,148 - 2\,595,5)}{600} \\ &= 4\,972,5 \text{ kJ/kg} \end{aligned} \quad (3)$$

2.6  $Q_{FLGAS} = mCp\Delta T$   
 $= (15 + 1) \times 1,045(210 - 24)$   
 $= 3109,92 \text{ kJ/kg}$  (2)

2.7

Q <sub>in</sub> (kJ /kg)	Q <sub>out</sub> (kJ /kg)	%
Q <sub>FUEL</sub> = 32 000	Q <sub>ECON</sub> = 1 836 Q <sub>EVAP</sub> = 19 831,5 Q <sub>SUPER</sub> = 4 972,5 Q <sub>FLUGAS</sub> = 3 109,92 Unaccounted = 2 250,08	5,74 61,97 15,54 9,72 7,03
32 000	32 000	100

(5)  
[20]

**QUESTION 3**

3.1  $\gamma = Cp/Cv = 1/0,712 = 1,4$

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

$$= 289 \left( \frac{13}{1} \right)^{1,4-1}$$

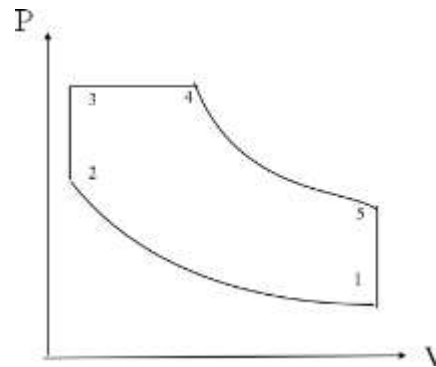
$$= 806,26 \text{ K}$$

$$T_2 = P_1 \left( \frac{V_1}{V_2} \right)^{\gamma}$$

$$= 10,325 \left( \frac{13}{1} \right)^{1,4}$$

$$= 3\,674,83 \text{ kPa}$$

(5)



3.2  $T_3 = \frac{T_2 \cdot P_3}{P_2}$   
 $= \frac{806,26 \times 5\,000}{3\,674,83}$   
 $= 1\,097 \text{ K}$  (2)



## QUESTION 4

4.1

$$\begin{aligned}
 T_{c'} &= T_1 \left( \frac{2}{\gamma + 1} \right) \\
 &= 753 \left( \frac{2}{1,4 + 1} \right) \\
 &= 627,5 \text{ K}
 \end{aligned}$$

$$\begin{aligned}
 \eta_{CONV} &= \frac{(T_1 - T_c)}{(T_1 - T_{c'})} \times \frac{100}{1} \\
 90 &= \frac{(753 - T_c)}{(753 - 627,5)} \times \frac{100}{1} \\
 \therefore T_c &= 640,05 \text{ K}
 \end{aligned}$$

$$\begin{aligned}
 P_c &= P_1 \left( \frac{2}{\gamma + 1} \right)^{\frac{\gamma}{\gamma - 1}} \\
 &= 3000 \left( \frac{2}{2,4} \right)^{\frac{1,4}{0,4}} \\
 &= 1584,85 \text{ kPa}
 \end{aligned}$$

$$\begin{aligned}
 V_c &= \frac{R \cdot T_c}{P_c} \\
 &= \frac{0,287 \times 640,05}{1584,85} \\
 &= 0,11591 \text{ m}^3
 \end{aligned}$$

$$\begin{aligned}
 C_c &= \sqrt{2000 \cdot C_p \cdot (T_1 - T_c) + C_1^2} \\
 &= \sqrt{2000 \times 1,005 (753 - 640,05) + 60^2} = 480,2 \text{ m/s}
 \end{aligned}$$

$$\begin{aligned}
 A_c &= \frac{m \cdot V_c}{C_c} \\
 &= \frac{1,2 \times 0,11591}{480,24} \\
 &= 289,63 \text{ mm}^2
 \end{aligned}$$

(10)

4.2

$$\begin{aligned}
 T_2' &= T_1 \left( \frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} \\
 &= 753 \left( \frac{600}{3000} \right)^{\frac{0,4}{1,4}} \\
 &= 475,43K \\
 \eta_{DIVER} &= \frac{(T_c - T_2)}{(T_c - T_2')} \times \frac{100}{1} \\
 85 &= \frac{(640,05 - T_2)}{(640,05 - 475,43)} \times \frac{100}{1} \\
 \therefore T_2 &= 500,12.K \\
 C_2 &= \sqrt{2000 \cdot Cp \cdot (T_1 - T_2) + C_1^2} \\
 &= \sqrt{2000 \times 1,005(753 - 500,12) + 60^2} = 715,46.m/s \\
 V_2 &= \frac{RT_2}{P_2} \\
 &= \frac{0,287 \times 500,12}{600} \\
 &= 0,23922m^3 \\
 A_2 &= \frac{mV_2}{C_2} \\
 &= \frac{1,2 \times 0,23922}{715,4} \\
 &= 401,26. mm^2 \tag{8}
 \end{aligned}$$

4.3

$$\begin{aligned}
 Mach..No &= \frac{C_2}{C_c} \\
 &= \frac{715,46}{480,24} \\
 &= 1,489 \tag{2}
 \end{aligned}$$

**[20]**

**QUESTION 5**

$$\begin{aligned}
 5.1 \quad B.P &= \frac{P_B \cdot LACE}{60} \\
 &= \frac{738 \times 1,5 \left(\frac{\pi}{4}\right) \times (0,76)^2 \times 112 \times 5}{60} \\
 &= 4\,687,07 \text{ kW} \quad (4)
 \end{aligned}$$

$$\begin{aligned}
 5.2 \quad \eta_{mech} &= \frac{BP}{IP} \cdot 100\% \\
 IP &= \frac{4\,687,07}{86,5} \cdot 100\% \\
 &= 5\,418,58 \text{ kW} \quad (2)
 \end{aligned}$$

$$\begin{aligned}
 5.3 \quad \eta_{BRAKE.THERMAL} &= \frac{BP}{mf / s.x.CV} \cdot 100\% \\
 &= \frac{4\,687,07}{\frac{1\,050}{3\,600} \times 44\,200} \cdot 100\% \\
 &= 36,36\% \quad (3)
 \end{aligned}$$

$$\begin{aligned}
 5.4 \quad BP &= \frac{2\pi NT}{60} \\
 4\,687,07 &= \frac{2\pi NT}{60} \\
 \therefore T &= 399,63 \text{ kNm} \quad (3)
 \end{aligned}$$

$$\begin{aligned}
 5.5 \quad V_1 &= \frac{mRT_1}{P_1} \\
 &= \frac{22 \times \frac{1\,050}{60} \times 0,287(16 + 273)}{101,325} \\
 \therefore V_1 &= 315,155 \text{ m}^3/\text{min} \quad (3)
 \end{aligned}$$

$$\begin{aligned}
 5.6 \quad V_s &= \frac{\pi}{4} D^2 \times L \times N \times E \\
 &= \frac{\pi}{4} (0,76)^2 \times 1,5 \times 112 \times 5 \\
 &= 381,063 \text{ m}^3/\text{min} \quad (3)
 \end{aligned}$$



5.7

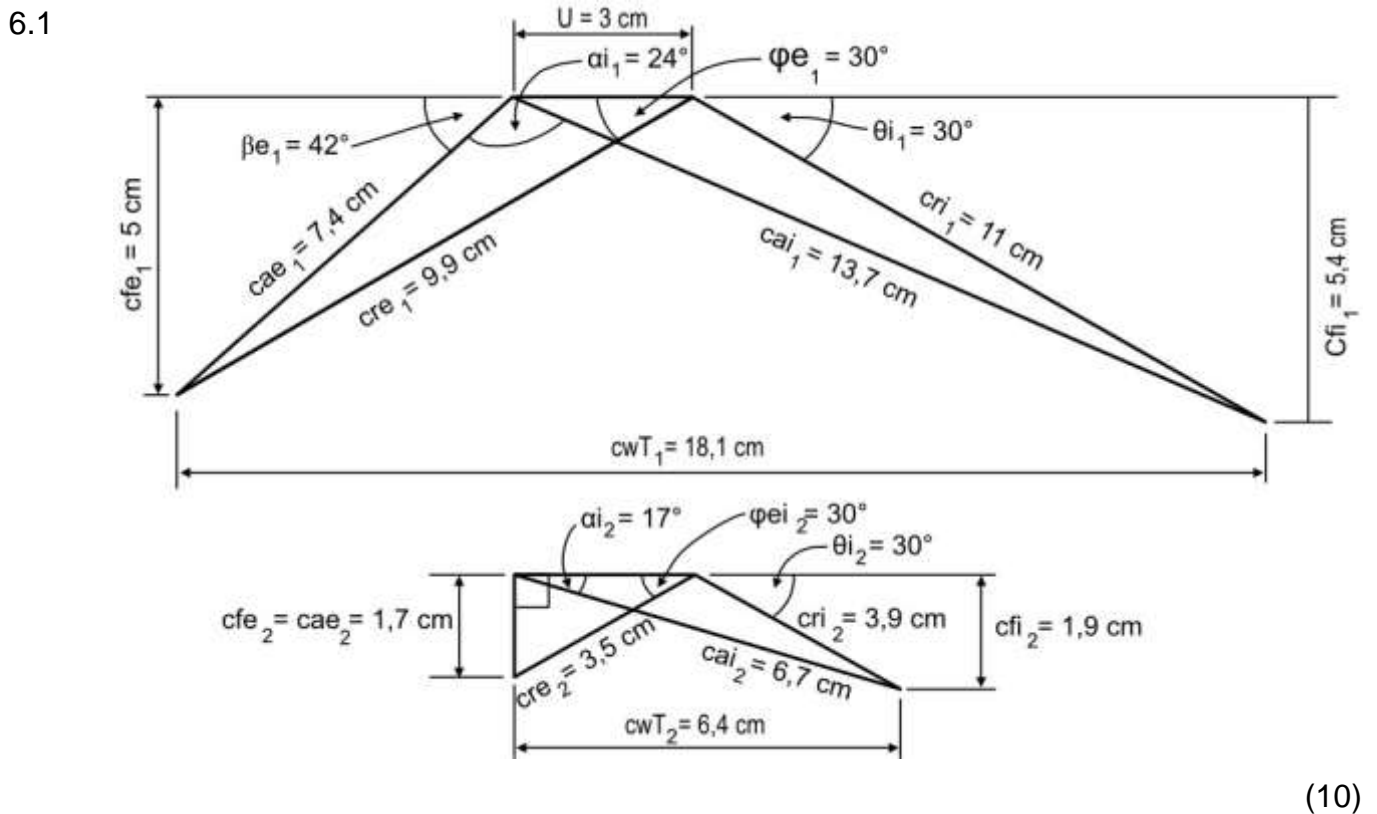
$$\eta_{VOL} = \frac{V_1}{V_s} \cdot 100\%$$

$$= \frac{315,155}{381,063} \cdot 100\%$$

$$= 82,70\%$$

(2)  
[20]

**QUESTION 6**



6.2 6.2.1  $U = 3 \times 36,5 = 110 \text{ m/s}$  (2)

6.2.2  $P = m \cdot u \cdot CwT = 1 \times 110 (660,65 + 233,6) = 98,37 \text{ kW}$  (3)

6.2.3

$$\eta = \frac{2UCw_T}{(Cai_1)^2} \cdot 100\%$$

$$= \frac{2 \times 110 (660,65 + 233,6)}{500^2} \cdot 100\%$$

$$= 78,69\%$$

(3)

$$\begin{aligned}
 6.2.4 \quad F_{axial} &= m[(Cfi_1 - Cfe_1) + (Cfi_2 - Cfe_2)] \\
 &= 1[(5,41 - 5) + (1,9 - 1,7)] \\
 &= 22,27 \text{ N}
 \end{aligned}$$

(2)  
[20]

**QUESTION 7**

$$\begin{aligned}
 7.1 \quad \text{Ideal C.O.P} &= \frac{T_1}{T_2 - T_1} \\
 &= \frac{267}{304 - 267} \\
 &= \frac{267}{37} \\
 &= 7,216
 \end{aligned}$$

$$\text{Actual C.O.P} = \eta \times \text{C.O.P}$$

$$= 0,9023 \times 7,216$$

$$= 6,511$$

(3)

$$\begin{aligned}
 7.2 \quad \text{C.O.P} &= \frac{h_1 - h_4}{h_2 - h_1} \\
 \text{C.O.P} &= (h_2 - h_1) = h_1 - h_4
 \end{aligned}$$

$$6,511 = (479 - h_1) = h_1 - 110,2$$

$$3118,769 + 110,2 = h_1 + 6,511h_1$$

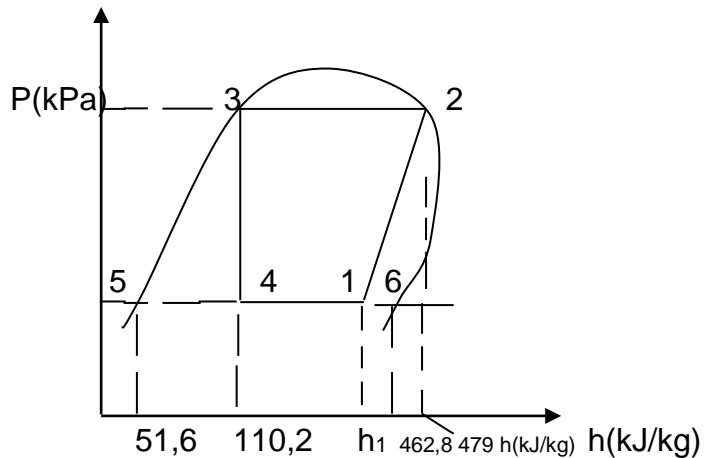
$$h_1 = \frac{3228,969}{7,511}$$

$$= 429,9 \text{ kJ/kg}$$

$$h_1 = h_5 + x_1(h_4 - h_5)$$

$$x_1 = \frac{h_1 - h_5}{h_6 - h_5} = \frac{429,9 - 51,6}{462,8 - 51,6} = \frac{378,8}{411,2} = 0,92$$

(5)



$$\begin{aligned}
 7.3 \quad V_s &= \frac{\pi D^2 L}{4} = \frac{\pi}{4} D^2 \times 1,2 D \\
 &= \frac{1,2 \times \pi D^3}{4} = \frac{1,2 \times \pi \times (0,1285)^3}{4} \\
 &= 0,002 \text{ m}^3/\text{s} \\
 V_s &= \frac{0,062 \times 420}{60} = 0,014 \text{ m}^3/\text{s} \\
 V_e &= V_s \times \eta_{\text{vol}} = 0,014 \times 0,9 = 0,0126 \text{ m}^3/\text{s} \quad (5)
 \end{aligned}$$

$$\begin{aligned}
 7.4 \quad V_1 &= x_1 \cdot V_{g1} = 0,92 \times 0,168 = 0,155 \text{ m}^3/\text{kg} \\
 m_r &= \frac{V_e}{v_1} = \frac{0,0126}{0,155} \times 60 = 4,88 \text{ kg}/\text{min} \quad (4)
 \end{aligned}$$

$$\begin{aligned}
 7.5 \quad P_c &= m_r (h_2 - h_1) = \frac{4,88}{60} (479 - 429,9) = \frac{4,88}{60} (49,1) \\
 &= 4 \text{ kJ}/\text{s}
 \end{aligned}$$

$$P_m = P_c / \eta_{\text{mec}} = \frac{4}{0,8} = 5 \text{ kW} \quad (3)$$

**[20]**

**TOTAL: 100**