



**higher education
& training**

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES N6

1 December 2022

This marking guideline consists of 7 pages.

QUESTION 1

1.1 It means that temperature after compression✓ is reduced to what it was before compression.✓ (2)

1.2 1.2.1
$$r_p = \sqrt{\frac{r_{del}}{p_1}} = \sqrt{\frac{9p_1}{p_1}} = 3$$

$$T_2 = T_1 (r_{p1})^{\frac{n-1}{n}} = 288 (3)^{\frac{0,3}{1,3}} = 371,106 \text{ K}$$

$$T_4 = T_2 = 371,106 \text{ K} \checkmark$$
 (4)

1.2.2
$$P_{out} = x \left[\frac{n}{n-1} m R T_1 \left(r_p^{\frac{n-1}{n}} - 1 \right) \right] \text{ (no mark if there is a PLUS sign)}$$

$$\checkmark 2 \left[\frac{1,3 \times 4,5 \times 0,287 \times 288}{0,3} \left(3^{\frac{0,3}{1,3}} - 1 \right) \right] \checkmark$$

$$\checkmark 930,1999 \times \frac{1}{60}$$

$$\checkmark 15,503 \text{ kW} \checkmark$$
 (3)

1.2.3
$$p_1 v_{ind1} = m R T_1 \implies v_{ind1} = \frac{4,5 \times 0,287 \times 288}{101,3} = 3,672 \frac{m^3}{min}$$

$$v_s = v_1 - v_c \implies v_1 = 1,05 v_s \wedge \checkmark$$

$$v_4 = v_c \times r_p^{\frac{1}{n}} = 0,05 v_s \times 3^{\frac{1}{1,3}} = 0,1164289 v_s$$

$$v_{ind} = v_1 - v_4 = 1,05 v_s - 0,1164289 v_s$$

$$v_s = \frac{3,672}{300(1,05 - 0,1164089)} = 13,11 \times 10^{-13} m^3 \checkmark$$
 (6)

1.2.4
$$\eta_{vol} = 1 - \frac{v_c}{v_s} \left[r_p^{\frac{1}{n}} - 1 \right] = 1 - 0,05 \left[3^{\frac{1}{1,3}} - 1 \right] = 0,934 \checkmark$$

$$p_3 v_3 = m R T_3 \implies v_3 = \frac{4,5 \times 0,287 \times 288}{3 \times 101,3 \times 300} = 4,08 \times 10^{-3} m^3$$

$$\eta_{vol} = \frac{v_{ind}}{v_s} \implies v_s = \frac{4,08 \times 10^{-3}}{0,934} = 4,37 \times 10^{-3} m^3 \checkmark$$
 (5)

[20]

QUESTION 2

- 2.1 Actual dryness fraction is the real/actual numerical measure of how close to saturation steam is. ✓ Isentropic dryness fraction is the dryness fraction that steam ✓ would have had if its entropy did not change. ✓ (3)

2.2 2.2.1
$$h_c = h_f + x h_{fg} = 640 + 0,96 \times 2107 = 2662,72 \frac{kJ}{kg}$$

$$h_1 = h_g = 2773 \frac{kJ}{kg}$$

$$C_c = \sqrt{2000(h_1 - h_c)} = \sqrt{2000(2773 - 2662,72)} = 469,64 m/s$$

$$v_c = x_c v_g = 0,96 \times 0,3747 = 0,3597 \frac{m^3}{kg}$$
 (8)

2.2.2
$$h_2 = h_f + x_{2a} h_{fg} = 584 + 0,945 \times 2147 = 2612,915 \frac{kJ}{kg}$$

$$H_2 = m h_2 = 0,645 \times 2612,915 = 1685,33 kJ$$

$$h_{2s} = h_f + x_{2s} h_{fg} = 584 + 0,929 \times 2147 = 2578,563 \frac{kJ}{kg}$$

$$H_{2s} = m h_{2s} = 0,645 \times 2578,563 = 1663,173 kJ$$

$$\eta_{noz} = \frac{h_1 - h_2}{h_1 - h_{2s}} = \frac{2773 - 2612,915}{2773 - 2578,563} = 0,8233$$
 (9)
[20]

QUESTION 3

- 3.1 To change the direction/angle ✓ of steam/gas/fluid ✓ as it flows from first to second stage ✓ of moving blades (3)
- 3.2 Refer to FIGURE 1 (last page)

Note:

- Each diagram has a maximum of FIVE marks.
- Marks are awarded specifically as shown by ticks (candidates were instructed to show all lengths and angles).
- NO mark if given length is not in centimetres.

Marker discretion is advised for variances of lengths and angles. (10)

3.2.1 $\beta = 26^\circ$ (1)

$$3.2.2 \quad F_{ax} = m(C_{f1} - C_{f2}) = 2,1 [40(5,5 - 4,7)] = 67,2 \text{ N} \checkmark \quad (3)$$

$$3.2.3 \quad \eta_{dia} = \frac{2U(\Delta V_w)}{V_1^2} = \frac{2 \times 117,8097(1040 + 424)}{700^2} = 70,4\% \quad (3)$$

[20]

QUESTION 4

4.1 In a thermodynamic cycle, the sum of the net heat✓ supplied into the systems and the network✓ input is zero.✓ (3)

4.2 4.2.1 $h_1 = 101 \frac{\text{kJ}}{\text{kg}}; h_2 = 351 \text{ kJ/kg}$

$$Q_{eco} = \frac{m_s}{m_f}(h_2 - h_1) \Rightarrow \frac{m_s}{m_f} = \frac{2100}{351 - 101} = 8,4 \frac{\text{kg}_s}{\text{kg}_f} \checkmark 8,4 \quad (4)$$

4.2.2 $h_4 = h_g + c_p(t_i - t_s) = 2802 + 3,1125(305 - 242,5)$

$$\checkmark 2996,53 \frac{\text{kJ}}{\text{kg}}$$

$$\eta_{plant} = \frac{m_s}{m_f} \times \frac{(h_4 - h_1)}{CV} = \frac{8,4(2996,53 - 101)}{32000} = 76,01\% \quad (4)$$

4.2.3 $h_3 = h_g + x h_{fg}$

$$\checkmark 1050 + 0,9787 \times 1752$$

$$\checkmark 2764,68 \frac{\text{kJ}}{\text{kg}}$$

$$Q_{evap} = \frac{m_s}{m_f}(h_3 - h_2) = 8,4(2764,68 - 351) = 20274,93 \frac{\text{kJ}}{\text{kg}}$$

$$Q_i = \frac{m_s}{m_f}(h_4 - h_3) = 8,4(2996,53 - 27764,68) = 1947,54 \frac{\text{kJ}}{\text{kg}}$$

$$Q_{aph} = m_a c_{pa}(t_{out} - t_i)$$

$$\checkmark 18 \times 1,005(119 - 25)$$

$$\checkmark 1700,46 \frac{\text{kJ}}{\text{kg}} \quad (6)$$

$$4.2.4 \quad Q_{ch3} = m_g c_{pg} (t_{out} - t_i)$$

$$19 \times 1,07 (177,09 - 25)$$

$$3091,99 \frac{kJ}{kg}$$

$$\% = \frac{Q_{chim}}{CV} = \frac{3091,99}{32000} \times 100 = 9,66 \%$$

(3)
[20]**QUESTION 5**

5.1 Indicated thermal efficiency is only theoretical✓ and measures how well is the fuel energy converted into indicated output power. Brake thermal efficiency is actual✓ efficiency and measures the amount of fuel thermal energy that gets converted into mechanical work or power.✓ (3)

5.2 5.2.1 $P_b = 0,5 p_b \times A l N n$ ✓

$$A l = \frac{\pi}{4} \times 0,212^2 \times 0,292 = 10,3073 \times 10^{-3} m^3$$

$$\therefore P_b = \frac{0,5 \times 593 \times 10,3073 \times 10^{-3} \times 720 \times 4}{60} = 146,689 kW$$
 (4)

5.2.2 $s f c_b = \frac{m}{P_b} \Rightarrow m = 0,226 \times 146,689 = 33,152 kg/h$ (3)

5.2.3 $\eta_{BT} = \frac{P_b}{m \times CV} = \frac{146,689 \times 3600}{33,152 \times 44200} = 36,039 \% \checkmark$ (3)

5.2.4 $v_s = 10,3073 \times 10^{-3} m^3$ (5.2.1)

$$v_{sTOT} = 4 \times 0,5 \times 10,3073 \times 10^{-3} = 20,615 \times 10^{-3}$$

$$flowrate, v_s = 720 \times 20,615 \times 10^{-3} = 14,843 \frac{m^3}{min}$$

$$m_{ind} = r_{AF} \times m = 25 \times 33,154 = 828,85 kg/h$$

$$p v_{ind} = m_{ind} RT \Rightarrow v_{ind} = \frac{828,85 \times 0,287 \times 288}{101,1 \times 60}$$

$$11,294 \frac{m^3}{min}$$

$$\eta_{vol} = \frac{v_{ind}}{v_s} = \frac{11,294}{14,843} = 0,761$$

(7)

QUESTION 6

6.1

$$T_{2s} = T_1 \left(\frac{p_2}{p_1} \right)^{\frac{\gamma-1}{\gamma}} = 293 \left(\frac{550}{95} \right)^{\frac{1,4-1}{1,4}} = 483,91 \text{ K} \checkmark$$

$$\eta_{ci} = \frac{T_{2s} - T_1}{T_2 - T_1} \Rightarrow T_2 = 293 + \frac{483,91 - 293}{0,83} = 523,012 \text{ K} \quad (4)$$

6.2

$$T_4 = T_3 \left(\frac{p_1}{p_2} \right)^{\frac{\gamma-1}{\gamma}} = 1143 \left(\frac{95}{550} \right)^{\frac{1,4-1}{1,4}} = 692,07 \text{ K}$$

$$\eta_{II} = \frac{T_3 - T_4}{T_3 - T_{4s}} \Rightarrow T_4 = 1143 - 0,8(1143 - 692,07) = 782,256 \text{ K} \quad (4)$$

6.3

$$P_{com} = m c_p (T_2 - T_1) = 10 \times 1,03 (523,012 - 293) = 2369,12 \text{ kW}$$

$$P_{turb} = m c_p (T_2 - T_1) = 10 \times 1,03 (1143 - 782,26) = 3715,62 \text{ kW}$$

$$P_{net} = P_{turb} - P_{comp} = 3715,62 - 2369,12 = 1346,502 \text{ kW} \quad (5)$$

6.4

$$Q_{\dot{i}} = m c_p (T_3 - T_2) = 10 \times 1,03 (1143 - 550) = 6107,9 \text{ kJ/s} \checkmark$$

$$\eta_{therm} = \frac{P_{net}}{Q_{\dot{i}}} = \frac{1346,502}{6107,9} = 22,045 \% \checkmark \quad (4)$$

6.5

$$R_{work} = \frac{P_{net}}{P_{turb}} = \frac{1346,502}{3715,62} = 0,36239 \quad (3)$$

[20]

TOTAL: 100

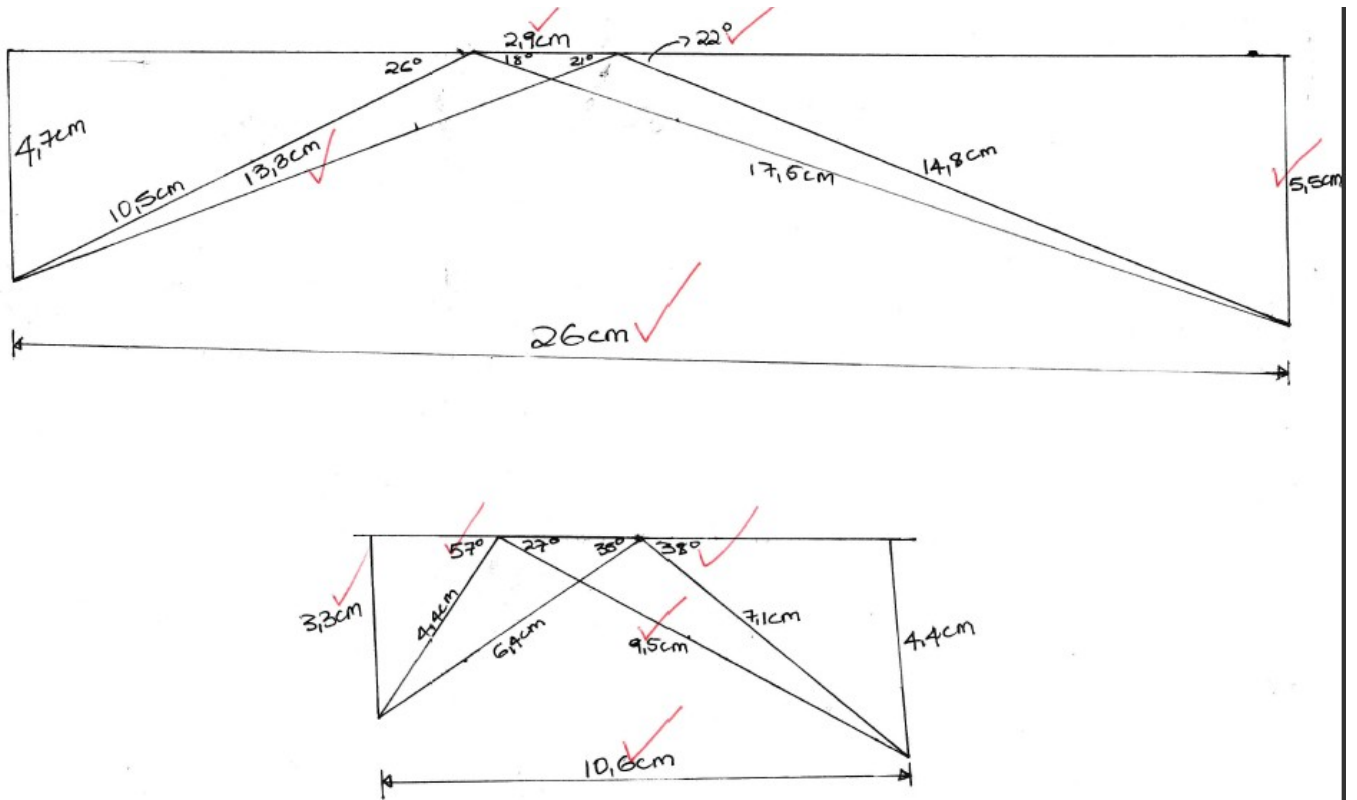


FIGURE 1