



higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES N6

18 April 2024

This marking guideline consists of 7 pages.

QUESTION 1

1.1 They cool cylinders and limit the temperature rise of the gas being compressed.

(2)

$$1.2 \quad 1.2.1 \quad \frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \checkmark \Rightarrow \frac{p_2}{p_1} = \left(\frac{487,67}{294,34}\right)^{\frac{1,308}{0,308}} = 1,657 \checkmark = r_{p1}$$

$$p_2 = r_{p1} \times p_1 = 1,657 \times 99,87 \checkmark = 165,485 \text{ kPa} \checkmark$$

$$r_{p2} = \frac{p_4}{p_3} = \frac{876}{165,485} = 5,294 \checkmark \quad (5)$$

$$1.2.2 \quad v_{cyl1} = \frac{v_{ind}}{N} = \frac{24}{486,75 \checkmark} = 0,049 \text{ m}^3 = 49,307 \text{ l} \checkmark$$

$$T_3 = T_2 - 0,3576T_2 = 487,67 - 0,3576 \times 487,67 = 313,247 \text{ K} \checkmark$$

$$\frac{p_1 v_1}{T_1} = \frac{p_3 v_3}{T_3} \checkmark \Rightarrow v_3 = \frac{99,87 \times 24 \times 313,247}{294,34 \times 165,485} = 15,414 \text{ m}^3/\text{min}$$

$$v_{cyl2} = \frac{v_3}{N} = \frac{15,414}{486,75} = 0,0317 \text{ m}^3 = 31,668 \text{ l} \checkmark \quad (5)$$

$$1.2.3 \quad P_{ind} = \frac{n}{n-1} \{ p_1 v_1 (r_{p1}^{\frac{n-1}{n}} - 1) + \checkmark p_3 v_3 (r_{p2}^{\frac{n-1}{n}} - 1) \} \checkmark$$

$$= \frac{1,308}{0,308} \left\{ \frac{99,87 \times 24}{60} \times (1,657 \checkmark^{\frac{0,308}{1,308}} - 1) + \frac{165,485 \times 15,414}{60} \times (5,294 \checkmark^{\frac{0,308}{1,308}} - 1) \right\}$$

$$= 108,057 \text{ kW} \checkmark \quad (4)$$

$$1.2.4 \quad P_{iso} = P_{iso1} + P_{iso2}$$

$$= p_1 v_1 \ln r_{p1} + \checkmark p_3 v_3 \ln r_{p2}$$

$$= \frac{99,87 \times 24 \ln 1,657 + 165,485 \times 15,414 \ln 5,294 \checkmark}{60 \checkmark}$$

$$= 91,025 \text{ kW} \checkmark \quad (4)$$

[20]

QUESTION 2

2.1 Saturation temperature is the temperature at which steam is completely dry✓
at a given pressure.✓ Superheated temperature is the temperature to which
steam is heated beyond saturation✓ at a given pressure.✓ (4)

2.2 2.2.1 $h_1 = 3248 \text{ kJ/kg} \checkmark$

$$h_c = h_g + c_p(t_{sup} - t_s) \checkmark$$

$$= 2789 \checkmark + 3,68(231,33 - 196,7 \checkmark) = 2916,44 \text{ kJ/kg} \checkmark \quad (5)$$

2.2.2 $h_{2s} = h_f + xh_{fg} \checkmark = 634 \checkmark + 0,946 \times 2112 = 2631,95 \text{ kJ/kg} \checkmark$

$$\eta_{exp} = \frac{h_c - h_{2a}}{h_c - h_{2s}} \checkmark \Rightarrow h_{2a} = 2916,44 - 0,836 \checkmark (2916,44 - 2631,95)$$

$$\therefore h_{2a} = 2678,61 \text{ kJ/kg} \checkmark \quad (6)$$

2.2.3 $C_c = \sqrt{2000(h_1 - h_c)} \checkmark = \sqrt{2000(3248 - 2916,44 \checkmark)} = 814,82 \text{ m/s} \checkmark$

$$C_c = \sqrt{2000(h_1 - h_2)} = \sqrt{2000(3248 - 2647,31 \checkmark)} = 1067,14 \text{ m/s} \checkmark \quad (5)$$

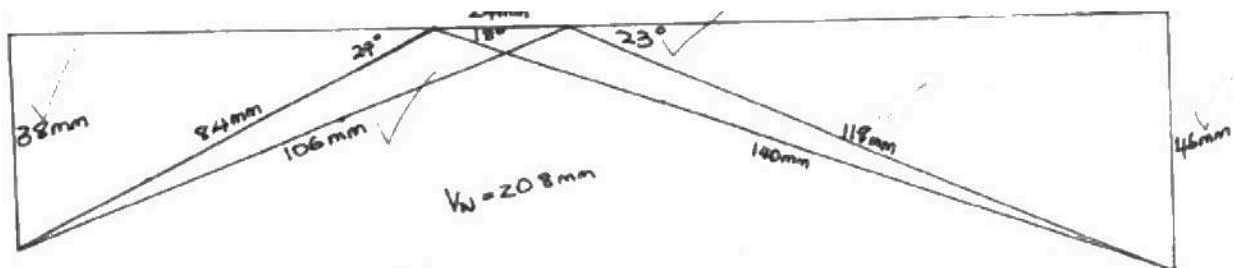
[20]

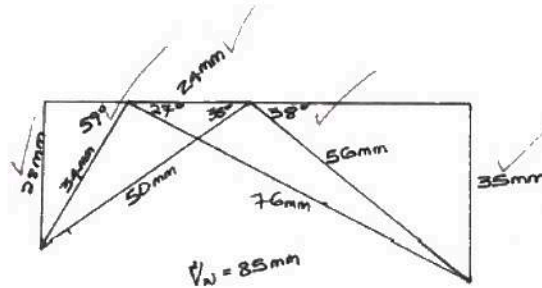
QUESTION 3

3.1 Because they work on the principle of change of momentum (2)
OR To differentiate them from other turbines such as reaction turbines

3.2 $U = \frac{\pi D \times N}{60} = \frac{0,75\pi \times 3000}{60} = 117,81 \checkmark \text{ m/s} \checkmark$

See the diagrams and notes below.





NOTES:

Candidates were instructed to indicate all lengths and angles on the diagrams, therefore:

- No mark may be awarded where length/angle is not indicated.
- The only acceptable unit of length is millimetre as per question paper instruction.
- Marks are to be allocated consistently, as shown on the diagrams.
- Reasonable allowances are permissible on the lengths and angles of the diagrams.

(12)

3.3 3.3.1 $V_w = \sum V_w = 5(208 + \sqrt{85}) = 1\,465\sqrt{\text{ m/s}}$

(2)

3.3.2 $E_K = 0,5 mv^2 = 0,5\sqrt{\text{ }} \times 1 \times (5 \times 34\sqrt{\text{ }})^2 = 14,45\sqrt{\text{ kJ/kg}}$

(4)

[20]

QUESTION 4

- 4.1
- To convert steam into liquid
 - To de-gas steam
 - To reduce the specific steam consumption of the plant
 - To maintain a low pressure at the turbine exit

(Any 3 × 1)

(3)

4.2 4.2.1 $Q_g = mc_{pg} \times \Delta t\sqrt{\text{ }} = 19,43 \times 1,06 \times (289 - 24,7) = 5\,443,45\sqrt{\text{ kJ/kg}}$

$$\%Q_g = \frac{Q_g}{m_f \times CV}\sqrt{\text{ }} = \frac{5\,443,45}{1 \times 33,6 \times 10^3} = 16,196\%\sqrt{\text{ }}$$

(5)

4.2.2 $h_1 = 405 \text{ kJ/kg}\sqrt{\text{ }}$

$$h_{2s} = h_f + xh_{fg} = 1\,004\sqrt{\text{ }} + 0,9682 \times 1\,798 = 2\,744,824 \text{ kJ/kg}\sqrt{\text{ }}$$

$$h_3 = h_g + c_p(t_{sup} - t_s)\sqrt{\text{ }}$$

$$= 2\,802\sqrt{\text{ }} + 2,3(271,46 - 232,9) = 2\,890,688 \text{ kJ/kg}\sqrt{\text{ }}$$

(12)

$$4.2.3 \quad \eta_{evap} = \frac{m_s(h_2 - h_1)}{m_f \times CV} = \frac{5\,165(2\,744,824\checkmark - 405)}{498 \times 33,6 \times 10^3} = 72,2\%\checkmark$$

$$\eta_{plant} = \frac{m_s(h_3 - h_1)}{m_f \times CV} = \frac{5\,165(2\,890,688\checkmark - 405)}{498 \times 33,6 \times 10^3} = 76,704\%\checkmark$$

$$\eta_{mech} = \frac{P_{mech}}{m_f \times CV} \checkmark = \frac{3,618 \times 3\,600}{498 \times 33,6} = 77,82\%\checkmark$$

(6)
[20]

QUESTION 5

5.1 Diesel common-rail injection (3)

$$5.2 \quad 5.2.1 \quad P_{br} = 0,5p_{bm}AlNn\checkmark = \frac{0,5\checkmark \times 593 \times 0,212^2 \times 0,292\pi \times 720 \times 4}{4 \times 60}$$

$$= 146,693 \text{ kW}\checkmark$$

$$sf c_{br} = \frac{m_f}{P_{br}} \checkmark \Rightarrow m_f = \frac{0,226 \times 146,693}{3\,600\checkmark} = 9,209 \times 10^{-3} \text{ kg/s}\checkmark \quad (6)$$

$$5.2.2 \quad \eta_{BT} = \frac{P_{br}}{m_f \times CV} \checkmark = \frac{146,693 \times 10^3}{44\,200\checkmark \times 9,209} = 36,04\%\checkmark \quad (3)$$

$$5.2.3 \quad \frac{m_a}{m_f} = 25 \Rightarrow m_a = 25 \times 9,209 \times 10^{-3} = 0,2302 \text{ kg/s}\checkmark$$

$$p_{atm}v_a = m_aRT_{atm}\checkmark \Rightarrow v_a = \frac{0,2302 \times 0,287 \times 288 \times 60}{102} = 11,193 \text{ m}^3/\text{min} \checkmark \quad (3)$$

$$5.2.4 \quad v_s = AlNn\checkmark = \frac{0,212^2 \times 0,292\pi \times 720 \times 4}{4 \times 2\checkmark} = 14,842 \text{ m}^3/\text{min} \checkmark$$

$$\eta_{vol} = \frac{v_a}{v_s} \checkmark = \frac{11,193}{14,842} = 75,41\%\checkmark \quad (5)$$

[20]

QUESTION 6

- 6.1 $T_{2s} = T_1(r_p)^{\frac{\gamma-1}{\gamma}} = 293 \times (5)^{\frac{0,4}{1,4}} = 464,06 \text{ K} \checkmark$
- $$\eta_C = \frac{T_{2s} - T_1}{T_2 - T_1} \Rightarrow T_2 = 293 + \left(\frac{464,06 - 293}{0,8} \right) = 506,83 \text{ K} \checkmark$$
- $$T_{4s} = T_3 \left(\frac{1}{r_p} \right)^{\frac{\gamma-1}{\gamma}} = 823 \left(\frac{1}{5} \right)^{\frac{0,33}{1,33}} = 552,04 \text{ K} \checkmark$$
- $$\eta_C = \frac{T_3 - T_4}{T_3 - T_{4s}} \checkmark \Rightarrow T_4 = 823 - 0,83(823 - 552,04) = 598,1 \text{ K} \checkmark \quad (7)$$
- 6.2 $W_c = c_{pa}(T_2 - T_1) = 1,01 \checkmark (506,83 - 293) = 215,97 \text{ kJ/kg} \checkmark$
- $$W_T = c_{pg}(T_3 - T_4) = 1,15 \checkmark (823 - 598,1) = 258,64 \frac{\text{kJ}}{\text{kg}} \checkmark (\text{sign not important}) \quad (4)$$
- 6.3 $P_c = \dot{m}_a W_c \checkmark = 15 \times 215,97 = 3\,239,55 \text{ kJ/s} \checkmark$
- $$P_T = \dot{m}_g W_T = 19,35 \times 258,64 = 5\,004,68 \text{ kJ/s} \checkmark$$
- $$\Sigma P = P_T - P_c = 5\,004,68 - 3\,239,55 = 1\,765,13 \text{ kJ/s} \checkmark (\text{sign not important}) \quad (4)$$
- 6.4 $Q_{in} = \dot{m}_g c_{pg}(T_3 - T_2) \checkmark = 19,35 \times 1,15(823 \checkmark - 506,83) = 7\,035,58 \text{ kJ/s} \checkmark$
- $$\eta_{cycle} = \frac{\Sigma P}{Q_{in}} \checkmark = \frac{1\,765,13}{7\,035,58} = 25,09\% \checkmark \quad (5)$$
- [20]**

QUESTION 7

- 7.1 Burning (heat addition) that occurs at constant volume (3)
- 7.2 7.2.1 $\eta_{cycle} = 1 - \left(\frac{1}{r_v} \right)^{\gamma-1} = 1 - \left(\frac{1}{7,5} \right)^{0,4} = 55,33\% \checkmark$
- $$\eta_{rel} = \frac{\eta_{BT}}{\eta_{cycle}} \checkmark \Rightarrow \eta_{BT} = 0,51 \checkmark \times 0,5533 = 28,23\% \checkmark \quad (6)$$
- 7.2.2 $\eta_{mech} = \frac{\eta_{BT}}{\eta_{iT}} \checkmark \Rightarrow \eta_{iT} = \frac{0,2823}{0,78 \checkmark} = 36,18\% \checkmark \quad (3)$

$$\begin{aligned} 7.2.3 \quad \eta_{iT} &= \frac{P_{ind}}{m_f \times CV} \checkmark \Rightarrow P_{ind} = \frac{0,3619 \times 1,75 \checkmark \times 46\,000}{3\,600} = 8,09 \text{ kW} \checkmark \\ \eta_{BT} &= \frac{P_{BT}}{m_f \times CV} \Rightarrow P_{BT} = \frac{0,2823 \times 1,75 \times 46\,000}{3\,600 \checkmark} = 6,32 \text{ kW} \checkmark \end{aligned} \quad (5)$$

$$7.2.4 \quad P_{br} = 2\pi NT \checkmark \Rightarrow T = \frac{6,32 \times 60 \checkmark \times 10^3}{2\pi \times 200} = 301,76 \text{ Nm} \checkmark \quad (3)$$

[20]

TOTAL: 100