



higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES N6

6 December 2024

This marking guideline consists of 7 pages.

QUESTION 1

1.1 Isothermal work is the theoretical✓ work that the compressor would have done if the temperature✓ remained unchanged✓ during compression. Indicated work is the polytropic/diagram✓ work as indicated on the cycle diagram of compression and expansion. (4)

1.2 1.2.1
$$p_1 v_{ind} = mRT_1 \checkmark \Rightarrow v_{ind} = \frac{12 \times 0,287 \times 302}{103} = 10,098 \text{ m}^3/\text{min}$$

$$\frac{v_{ind}}{N} = \frac{10,098}{5,5 \times 60} \times 1000 = 30,5998 \text{ l} \checkmark$$

$$\eta_{vol} = \frac{v_{ind}}{v_s} \checkmark = \frac{30,5998}{34,004} = 0,8999 \checkmark$$
 (4)

1.2.2
$$p_3 = p_2 = r_p p_1 = 4 \times 103 = 412 \text{ kPa}$$

$$v_{ind2} = \frac{mRT_3}{Np_3} = \frac{12 \times 0,287 \times 302 \checkmark \times 1000}{5,5 \times 60 \times 412 \checkmark} = 7,65 \text{ l} \checkmark$$

$$\eta_{vol} = 1 - \frac{v_c}{v_s} \left[r_p^{\frac{1}{n}} - 1 \right] \checkmark = 1 - 0,04 \checkmark \left[4^{\left(\frac{1}{1,35}\right)} - 1 \right] = 0,92831 \checkmark$$

$$\eta_{vol} = \frac{v_{ind}}{v_s} \Rightarrow v_s = \frac{7,65}{0,92831} = 8,241 \text{ l} \checkmark$$

$$v_{cyl} = v_c + v_s \checkmark = 0,04v_s + v_s = 1,04 \times 8,241 = 8,57 \text{ l} \checkmark$$
 (9)

1.2.3
$$T_{del} = T_2 = T_1 \times r_p^{\left(\frac{n-1}{n}\right)} \checkmark = 302 \checkmark \times 4^{\frac{0,35}{1,35}} = 432,61 \text{ K} = 159,61 \text{ }^\circ\text{C} \checkmark$$
 (3)
[20]

QUESTION 2

2.1 Faster✓ than the speed of sound✓ (2)

2.2 2.2.1
$$h_1 = h_g = 2731 \frac{\text{kJ}}{\text{kg}} \checkmark \text{ and } \Delta h = h_1 - h_c \Rightarrow h_c = 2731 - 97 = 2634 \frac{\text{kJ}}{\text{kg}} \checkmark$$

$$h_g = h_f + x_c h_{fg} \Rightarrow x_c = \frac{2634 - 505 \checkmark}{2202} = 0,9668 \checkmark$$

$$v_c = x_c v_g = 0,9668 \times 0,8854 \checkmark = 0,856 \text{ m}^3/\text{kg} \checkmark$$
 (6)

2.2.2
$$C_c = \sqrt{2000 \times \Delta h} \checkmark = \sqrt{2000 \times 97 \checkmark} = 440,454 \frac{\text{m}}{\text{s}} \checkmark$$

$$A_c = \frac{m v_c}{C_c} \checkmark = \frac{0,113 \times 0,856 \times 10^6}{440,454} = 219,61 \text{ mm}^2 \checkmark$$
 (5)

$$\begin{aligned}
 2.2.3 \quad c_2 &= \sqrt{2000 \times \Delta h} = \sqrt{2000 \times 534 \times 0,88} \checkmark = 969,453 \frac{m}{s} \checkmark \\
 h_1 - h_2 &= 534 \times 0,88 \checkmark \Rightarrow h_2 = 2731 - 534 \times 0,88 = 2261,08 \frac{kJ}{kg} \checkmark \\
 h_2 &= h_f + x_2 h_{fg} \Rightarrow x_2 = \frac{2261,08 - 192 \checkmark}{2393 \checkmark} = 0,8646 \checkmark
 \end{aligned}$$

(7)
[20]

QUESTION 3

3.1 False (2)

3.2 Refer to FIGURE 3 below.

NOTE: Candidates were instructed to indicate all lengths and angles on the diagrams. (12)

$$3.3.1 \quad V_{w1} = 1095 \checkmark \frac{m}{s} \checkmark$$

$$3.3.2 \quad V_{w2} = 470 \checkmark \frac{m}{s} \checkmark$$

$$3.3.2 \quad \eta = \frac{2U(\sum V_w)}{V_1^2} \checkmark = \frac{2 \times 150(1095 + 470)}{800^2} = 73,36 \% \checkmark$$

(3 × 2) (6)

[20]

4.1 The amount of heat energy which a kilogram of steam has

The heat energy which a kilogram of steam has due to its pressure and temperature

The sum of the internal energy and the product of pressure and volume of a unit kilogram of steam.

(4)

$$\begin{aligned} 4.2 \quad 4.2.1 \quad h_{sup} &= h_g + c_p(t_{sup} - t_s) = 2792 \checkmark + 2,3(230 - 202.9) = 2854,33 \frac{kJ}{kg} \checkmark \\ \dot{H} &= \dot{m}_s h_{sup} \checkmark = 66,667 \times 2854,33 \times 60 \times 10^{-3} = 11,417 \text{ MJ/h} \checkmark \end{aligned}$$

$$\begin{aligned}
 4.2.2 \quad h_3 &= h_f + xh_{fg} = 865\checkmark + 0,9728 \times 1927 = 2739,586 \text{ kJ/kg}\checkmark \\
 \text{Energy into the Superheater, } \dot{E}_{sup} &= \dot{m}_s h_3 = \frac{66,667 \times 2739,586}{60\checkmark} \\
 &= 3043,998 \frac{\text{kJ}}{\text{s}}\checkmark \\
 \eta_{tur} &= \frac{P_{turb}}{\dot{E}_{sup}} = \frac{277}{3043,998} = 9,1\% \checkmark
 \end{aligned}
 \tag{5}$$

$$4.2.3 \quad EE = \frac{m_s(h_{sup} - h_1)}{m_f \times 2257} = \frac{66,667(2854,33\checkmark - 207\checkmark)}{6,667 \times 2257} = 11,73\checkmark
 \tag{3}$$

$$4.2.4 \quad \eta = \frac{P_{turb}}{m_f \times CV} \checkmark = \frac{277\checkmark \times 60\checkmark \times 100}{6,667 \times 32 \times 10^3} = 7,79\% \checkmark
 \tag{4}$$

[20]

QUESTION 5

$$5.1 \quad \text{Spark}\checkmark \text{ ignition}\checkmark
 \tag{2}$$

$$5.2 \quad 5.2.1 \quad P_{brake} = 2\pi NT\checkmark = \frac{2\pi \times 240 \times 11,860}{60\checkmark} = 298,074\checkmark \text{ kW}
 \tag{3}$$

$$5.2.2 \quad V_{pist.} = \left(\frac{N \times l}{60}\right)\checkmark \times \text{Cylinders} = \left(\frac{240}{60} \times 0,585\checkmark\right) \times 2\checkmark = 4,68 \text{ m/s}\checkmark
 \tag{4}$$

$$5.2.3 \quad v_s = \left(\frac{\pi \times d^2}{4}\right)l = \frac{\pi \times 0,38^2}{4} \times 0,585 = 0,066346 \text{ m}^3\checkmark \text{ per cylinder}$$

$$\text{Total volume} = 2v_s = 0,13269\checkmark \text{ m}^3$$

$$\dot{v}_s = \frac{N}{2} \times \text{total volume} = \frac{240 \times 0,13269}{2\checkmark \times 60} = 0,26538 \text{ m}^3/\text{s}\checkmark
 \tag{4}$$

$$5.2.4 \quad \eta_{vol} = \frac{\dot{v}_{ind}}{\dot{v}_s} \checkmark \Rightarrow \dot{v}_{ind} = 0,26538 \times 0,85 = 0,22557 \text{ m}^3/\text{s}\checkmark
 \tag{2}$$

$$5.2.5 \quad \dot{v}_{fuel} = \frac{\dot{v}_{ind}}{7\checkmark} = \frac{0,22557}{7} = 0,03222 \text{ m}^3/\text{s}\checkmark$$

$$\eta_{bT} = \frac{P_{brake}}{\dot{v}_{fuel} \times CV} \checkmark = \frac{298,074}{0,03222 \times 38600\checkmark} = 23,96\% \checkmark
 \tag{5}$$

[20]

QUESTION 6

6.1 Refer to FIGURE 6 and the notes below:

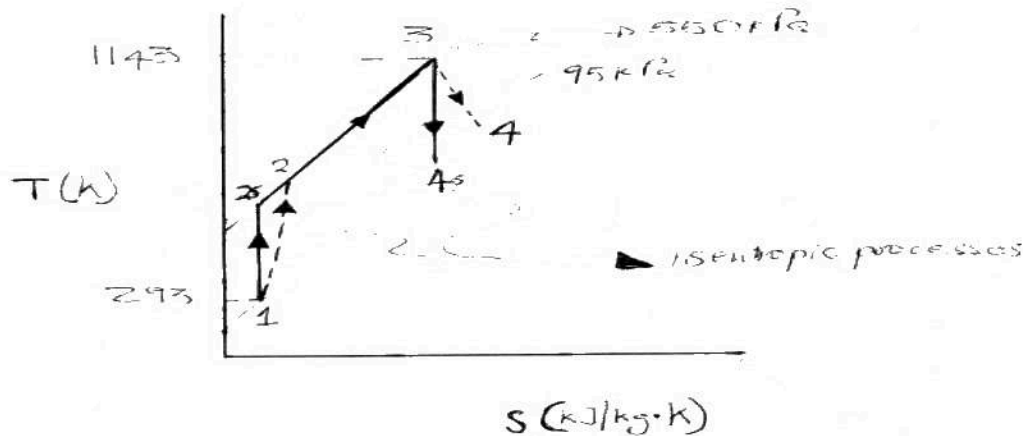


FIGURE 6

Notes:

- 1 mark for any one temperature value in correct position
- 1 mark for any one isentropic process indicated
- 1 mark for any correctly indicated arrow
- 1 mark for labelling temperature on the y-axis
- 1 mark for labelling entropy on the x-axis

(5)

6.2

$$T_{2s} = T_1 \times r_p^{\left(\frac{\gamma-1}{\gamma}\right)} = 293 \left(\frac{550}{95}\right)^{\frac{0,4}{1,4}} = 483,91 \text{ K} \checkmark$$

$$\eta_c = \frac{T_{2s} - T_1}{T_2 - T_1} = 293 + \left(\frac{483,91 - 293}{0,83}\right) = 523,01 \text{ K} \checkmark$$

$$T_{4s} = T_3 \times \left(\frac{p_4}{p_3}\right)^{\left(\frac{\gamma-1}{\gamma}\right)} = 1143 \left(\frac{95}{550}\right)^{\frac{0,4}{1,4}} = 692,07 \text{ K} \checkmark$$

$$\eta_T = \frac{T_3 - T_4}{T_3 - T_{4s}} \Rightarrow T_4 = 1143 - 0,8 \checkmark (1143 - 692,07) = 782,26 \text{ K} \checkmark$$

(9)

6.3

$$W_c = mc_p(T_2 - T_1) \checkmark = 10 \times 1(523,01 \checkmark - 293) = 2300,1 \text{ kW} \checkmark$$

$$W_T = mc_p(T_4 - T_3) \checkmark = 10 \times 1(782,26 - 1143 \checkmark) = -3607,04 \text{ kW} \checkmark$$

(6)

[20]

QUESTION 7

7.1 Refer to FIGURE 7 below

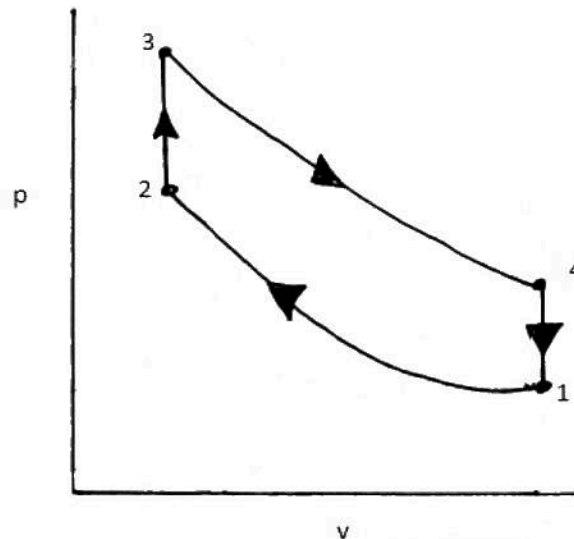


FIGURE 7

- 1 to 2 – (adiabatic) compression ✓
- 2 to 3 – (isobaric) heating ✓
- 3 to 4 – (adiabatic) expansion ✓
- 4 to 1 – (isobaric) cooling ✓

NOTES:

- 1 mark for a graph that resembles an Otto cycle
- 1 mark for one arrow in the clockwise direction
- 1 mark for labelling pressure on the vertical axis
- 1 mark for labelling volume on the horizontal axis

(8)

7.2 7.2.1 $Q = c_v(T_3 - T_2) \checkmark \Rightarrow T_2 = 1673 \checkmark - \frac{800}{0,718} = 558,793 \text{ K} \checkmark$

7.2.2 $\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} \checkmark = \frac{T_2}{T_1} = r_v^{\gamma-1} \Rightarrow r_v = \left(\frac{558,793}{288 \checkmark}\right)^{\frac{1}{0,4}} = 5,24 \checkmark$

7.2.3 $\eta_{cycle} = 1 - \frac{1}{(r_v)^{\gamma-1}} \checkmark = 1 - \frac{1}{5,24^{0,4} \checkmark} = 48,46\% \checkmark$

7.2.4 $\frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{\gamma-1} \checkmark = \left(\frac{v_2}{v_1}\right)^{\gamma-1} = \left(\frac{1}{r_v}\right)^{\gamma-1} = \left(\frac{1}{5,24 \checkmark}\right)^{1,4-1} = 0,5155$

$\therefore T_4 = 1673 \times 0,5155 = 862,509 \text{ K} \checkmark$

(3 × 4)

(12)
[20]

TOTAL: