higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES N6

7 December 2023

This marking guideline consists of 8 pages.

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QUESTION 1

1.1 $$r_p = \sqrt[x]{\frac{p_{del}}{p_1}}\checkmark = \sqrt[3]{\frac{1600}{100}} = 2{,}520\checkmark = \frac{p_2}{p_1}$$

$$\Longrightarrow p_2 = 2{,}520 \times 100 = 251{,}984\ kPa\checkmark (pressure\ in\ cooler\ 1)$$

$$r_p = \frac{p_4}{p_3}\checkmark \Longrightarrow p_4 = 2{,}520 \times 251{,}984 = 635{,}000\ kPa\checkmark\ (pressure\ in\ cooler\ 2)$$ (5)

1.2 $$\eta_{vol} = 1 - \frac{v_c}{v_s}\left(r_p^{\frac{1}{n}} - 1\right)\checkmark = 1 - 0{,}0546\left(2{,}520^{\frac{1}{1{,}288}} - 1\right) = 0{,}943\ or\ 94{,}270\%\checkmark$$

$$p_1 v_1 = mRT_1\checkmark \Longrightarrow v_1 = \frac{19{,}025 \times 0{,}296 \times 290\checkmark}{100} = 16{,}331\ {}^{m^3}/_{min}$$

$$per\ hour: 60 \times 16{,}331 = 979{,}864\ {}^{m^3}/_{h}$$

$$per\ shift: 8\checkmark \times 979{,}864 = 7838{,}909\ {}^{m^3}/_{shift}\checkmark$$ (6)

1.3 $$P_{ind} = x\left\{\frac{n}{n-1} \times mRT_1 \times \left[r_p^{\frac{n-1}{n}} - 1\right]\right\}\checkmark$$ OR

$$P_{ind} = x\left\{\frac{n}{n-1} \times p_1 v_1 \times \left[r_p^{\frac{n-1}{n}} - 1\right]\right\}$$

$$\therefore P_{ind} = 3\checkmark\left\{\frac{1{,}288 \times 19{,}025 \times 0{,}296 \times 290}{0{,}288 \times 60\checkmark} \times \left[2{,}52^{\frac{0{,}288}{1{,}288}} - 1\right]\right\} = 83{,}835\ kW\checkmark$$

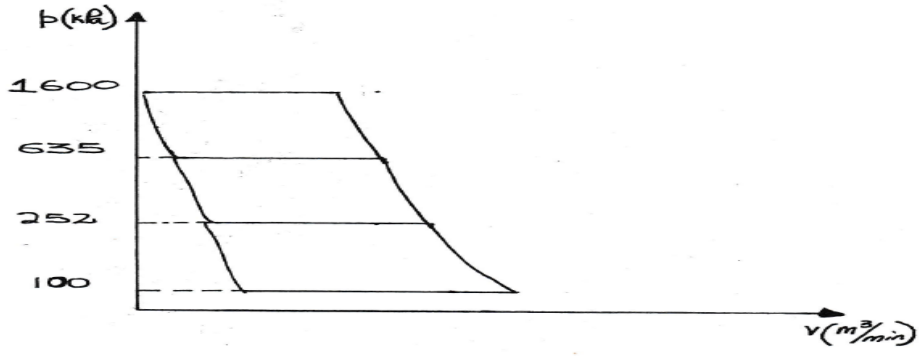
OR

$$\therefore P_{ind} = 3\left\{\frac{1{,}288 \times 100 \times 16{,}331}{0{,}288 \times 60} \times \left[2{,}52^{\frac{0{,}288}{1{,}288}} - 1\right]\right\} = 83{,}835\ kW$$ (4)

1.4 Refer to the notes and the diagram below

Notes:

- 1 mark for labelling pressure on the vertical axis
- 1 mark for labelling volume on the horizontal axis
- 3 marks for any THREE pressure values in correct positions



(5)

[20]

QUESTION 2

2.1 $h_c = h_f + xh_{fg}$✓ $= 682 + 0{,}9782$✓ $\times 2077 = 2713{,}721\ kJ/kg$✓

$h_2 = h_f + xh_{fg} = 546 + 0{,}9373$✓ $\times 2174 = 2583{,}690\ kJ/kg$✓ (5)

2.2 $C_c = \sqrt{2000(h_1 - h_c)}$✓ $= \sqrt{2000(2780$✓ $- 2713{,}721)} = 364{,}085\ m/s$✓

$C_2 = \sqrt{2000(h_1 - h_2)} = \sqrt{2000(2780 - 2583{,}690$✓$)} = 626{,}594\ m/s$✓ (5)

2.3 $v_c = x_c v_g$✓ $= 0{,}9782 \times 0{,}2968$✓ $= 0{,}290\ {}^{m^3}/_{kg}$ ✓

$v_2 = x_2 v_g = 0{,}9373 \times 0{,}6684$✓ $= 0{,}627\ {}^{m^3}/_{kg}$ ✓ (5)

2.4 $A_c = m \times \frac{v_c}{C_c}$✓ $= \frac{0{,}75 \times 0{,}290 \times 10^6$✓$}{364{,}085} = 597{,}388\ mm^2$✓

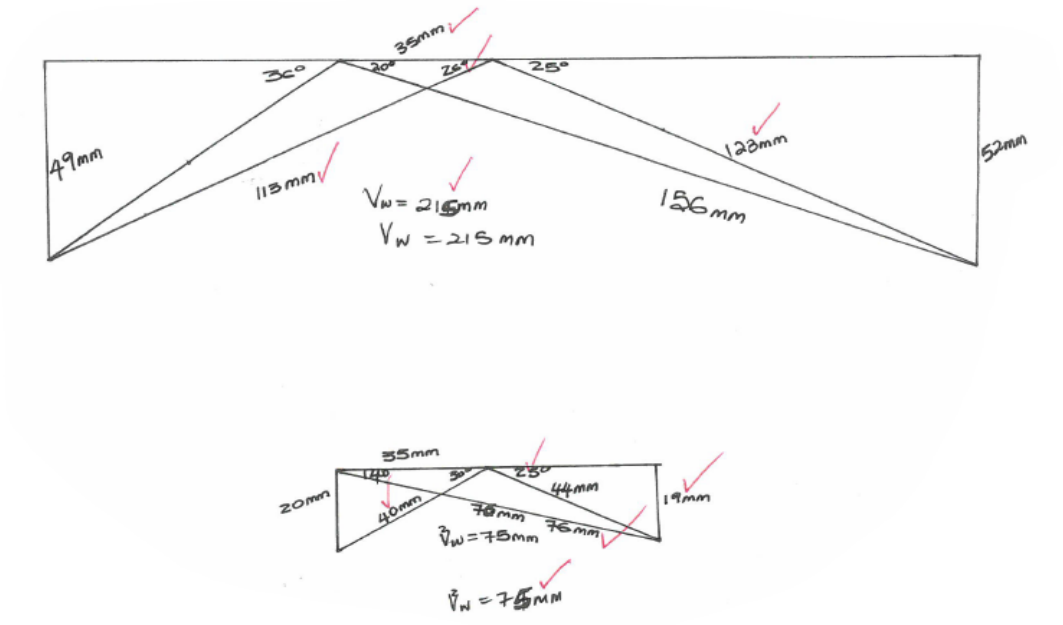
$A_2 = m \times \frac{v_2}{C_2} = \frac{0{,}75$✓ $\times 0{,}627 \times 10^6}{626{,}594} = 750{,}486\ mm^2$✓ (5)

[20]

QUESTION 3

3.1 False (2)

3.2 $U = \frac{2\pi rN}{60} = \frac{2\pi \times 0{,}605 \times 1650}{60} = \frac{104{,}54m}{s}$✓ $= 35\ mm$



Marks to be allocated as shown in the diagrams; mm is the only acceptable unit of length. (11)

3.2.1 $\alpha = 20°$✓

$$P = mU\left(\sum V_w\right)\checkmark = 104{,}54 \times [3(75 + 215)] = 90{,}95\checkmark\ {}^{kJ}/_{kg}\checkmark$$ (4)

3.2.2 $$\eta = \frac{2U(\sum V_w)}{{V_1}^2}\checkmark = \frac{2 \times 104{,}54 \times [3(75 + 215)]}{(3 \times 156\checkmark)^2} = 83{,}05\%\checkmark$$ (3)

[20]

QUESTION 4

4.1 Entropy (2)

4.2 4.2.1 $Q_{aph} = m_a c_{pa}(T_{in} - T_{out})\checkmark = 18{,}95\checkmark \times 1{,}02(129{,}13 - 12{,}67)$

$= 2251{,}06\ {}^{kJ}/_{kg}\checkmark$

$$\%Q_{aph} = \frac{Q_a}{CV} = \frac{2251{,}06 \times 100}{36{,}3 \times 10^3} = 6{,}20\%\checkmark$$ (4)

4.2.2 $Q_{eco} = m_s(h_{out} - h_{in}) = 11{,}37(630\checkmark - 341\checkmark) = 3285{,}93\ {}^{kJ}/_{kg}\checkmark$

$$\%Q_{eco} = \frac{Q_{eco}}{CV} = \frac{3285{,}93 \times 100}{36{,}3 \times 10^3} = 9{,}05\%\checkmark$$ (4)

4.2.3 $h_3 = h_f + xh_{fg}\checkmark = 1008\checkmark + 0{,}867 \times 1794 = 2563{,}398\ {}^{kJ}/_{kg}\checkmark$

$$EE = \frac{m_s(h_3 - h_2)}{m_f \times 2257}\checkmark = \frac{11{,}37(2563{,}398 - 630\checkmark)}{2257} = 9{,}74\checkmark\ {}^{kg_s}/_{kg_f}$$ (6)

4.2.4 $$\eta = \frac{m_s(h_4 - h_1)}{m_f \times CV}\checkmark = \frac{11{,}37(2995\checkmark - 341\checkmark)}{36{,}3 \times 10^3} = 0{,}8313\checkmark$$ (4)

[20]

QUESTION 5

5.1 Indicated power is developed inside the cylinder by gases and pistons; ✓ the brake power is developed externally✓ at the output shaft.✓

OR

Indicated power is a theoretical/indicator diagram power while brake power is the actual/mechanical output power as measured at the crankshaft. (3)

5.2 5.2.1

$$v_s = \frac{\pi d^2 l}{4} = \frac{\pi \times 0{,}17843^2 \times 0{,}25701 \times 10^6}{4} = 6426{,}517 cm^3 ✓$$

$$v_{cyl} = v_s + v_c ✓ = 6426{,}517 + 410 ✓ = 6836{,}517 ✓ cm^3 ✓$$ (5)

5.2.2

$$P_{ind} = p_m v_s \times Nn ✓ = \frac{755 \times 6426{,}517 \times 10^{-6} \times 375{,}08 \times 6 ✓}{60}$$

$$= 181{,}99 ✓ \ kW$$ (3)

5.2.3

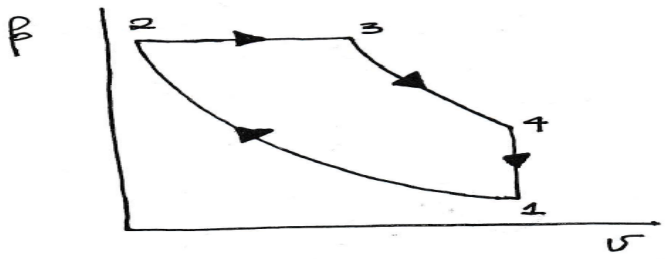
$$p_4 {v_4}^n = p_3 {v_3}^n \Longrightarrow p_3 = p_4 \left(\frac{v_4}{v_3}\right)^n ✓ \quad and$$

$$v_3 = v_c + \frac{21{,}6 v_s}{257{,}01} = 410 + \frac{21{,}6 ✓ \times 6426{,}517}{257{,}01} 950{,}106 ✓ cm^3$$

$$thus, p_3 = 390 ✓ \left(\frac{6836{,}517 ✓}{950{,}106}\right)^{1{,}33} = 5382{,}18 \ kPa ✓ = p_2$$

$$p_1 {v_1}^n = p_2 {v_2}^n \Longrightarrow p_1 = p_2 \left(\frac{v_2}{v_1}\right)^n$$

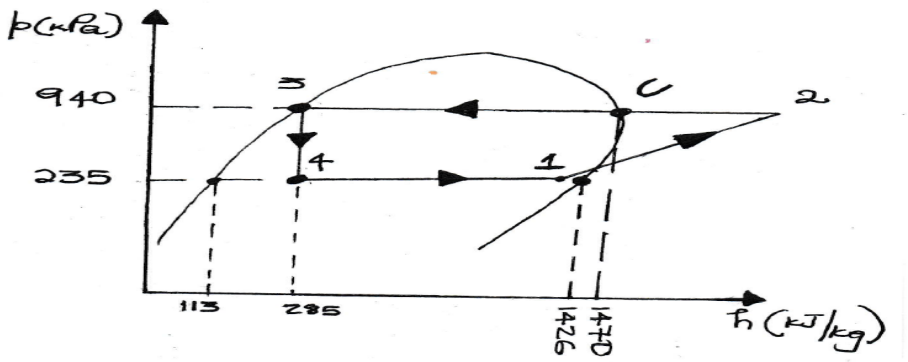
$$p_1 = 5382{,}18 \left(\frac{410 ✓}{6836{,},517 ✓}\right)^{1{,}33} = 127{,}535 \ kP ✓$$



(9)
[20]

QUESTION 6

6.1 Refer to the notes and diagram below:



Notes:
- 1 mark for pressure and enthalpy labelled on y- and x-axis respectively
- 1 mark for all FOUR arrows in the anti-clockwise direction
- 2 marks for any two enthalpy values in the correct positions
- 1 mark for position 2 (compressor exit) in the superheated region (5)

6.2 $h_1 = h_f + xh_{fg}$✓ $= 113 + 0{,}976(1426 - 113) = 1394{,}488\ {}^{kJ}/_{kg}$ ✓

$h_2 = h_3 +$ ✓$c_p(\Delta t) = 1470 + 4{,}211(329{,}96$✓ $- 297) = 1608{,}795\ {}^{kJ}/_{kg}$ ✓ (5)

6.3 $h_4 = h_3 = h_f = 285\ {}^{kJ}/_{kg}$ ✓

$h_4 = h_f + x_4 h_{fg} \implies x_4 = \dfrac{285\text{✓} - 113}{1426 - 113} = 0{,}131$✓

$s_4 = s_f + x_4 s_{fg}$✓ $= 0{,}46$✓ $+ 0{,}131(5{,}5 - 0{,}46) = 1{,}12\ {}^{kJ}/_{kg.K}$ ✓ (6)

6.4 $W_c = \dot{m}_f(h_2 - h_1)$✓ $= \dfrac{4{,}36}{60\text{✓}}(1608{,}795\text{✓} - 1394{,}488) = 15{,}573\ kW$✓ (4)

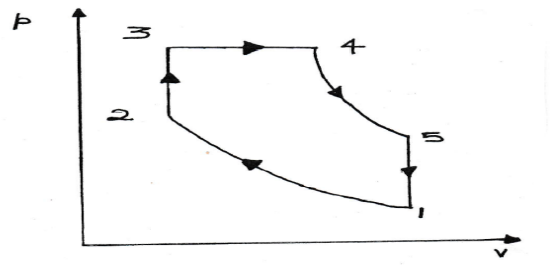
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QUESTION 7

7.1 Gross heat addition is the sum of all heat added without any loss.✓ Nett heat addition is the difference between✓ all heat added and the heat rejected (lost).✓ (3)

7.2 7.2.1 $T_2 = T_1(r_v)^{\gamma-1}$✓ $= 290 \times 18^{0,4} = 921,525\ K$✓

$p_2 = p_1(r_v)^{\gamma}$✓ $= 100 \times 18^{1,4} = 5719,809\ kPa$✓



(4)

7.2.2 $\frac{p_2v_2}{T_2} = \frac{p_3v_3}{T_3}$✓ $\Rightarrow T_3 = \frac{7000✓ \times 921,525}{5719,809} = 1127,778K$✓ (3)

7.2.3 $\frac{v_5}{v_4} = \frac{v_1}{v_4} = \frac{v_1 \times v_3}{v_4 \times v_3}$ $i.e.$ $\frac{v_5}{v_4} = \left(\frac{v_1}{v_2}\right)\left(\frac{v_3}{v_4}\right)$

$and\ \frac{p_3v_3}{T_3} = \frac{p_4v_4}{T_4}$✓ $\Rightarrow \frac{v_3}{v_4} = \frac{T_3}{T_4} = \frac{1127,778}{2273} = 0,4962$✓

$\therefore \frac{v_5}{v_4} = \left(\frac{v_1}{v_2}\right)\left(\frac{v_3}{v_4}\right) = 18 \times 0,4962 = 8,9309$ ✓

$\frac{T_5}{T_4} = \left(\frac{v_4}{v_5}\right)^{\gamma-1}$ ✓ $\Rightarrow T_5 = T_4\left(\frac{v_4}{v_5}\right)^{\gamma-1} = 2273\left(\frac{1}{8,9309}\right)^{0,4}$
$= 946,763\ K$✓ (5)

7.2.4 $Q_{cv} = mc_v(T_3 - T_2)$✓ $= 2 \times 0,718(1127,778✓ - 921,525)$
$= 296,178\ {}^{kJ}/_{S}$ ✓

$Q_{cv} = mc_v(T_1 - T_5) = 2 \times 0,718(290✓ - 946,763)$
$= 943,112\ {}^{kJ}/_{S}$ ✓ (5)

TOTAL: 100

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