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.

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QUESTION 1

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

1.2 1.2.1

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

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

$$T_4 = T_2 = 371,106\ K ✓$$ (4)

1.2.2 $P_{out} = x\left[\frac{n}{n-1} mRT_1\left(r_p{}^{\frac{n-1}{n}} - 1\right)\right]$ ✓ (no mark if there is a PLUS sign)

$$= 2\left[\frac{1,3\times4,5\times0,287\times288}{0,3}\left(3^{\frac{0,3}{1,3}} - 1\right)\right] ✓$$

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

$$= 15,503\ kW ✓$$ (3)

1.2.3 $p_1 v_{ind1} = mRT_1 ✓ \Longrightarrow v_{ind1} = \frac{4,5\times0,287\times288}{101,3} = 3,672\ {}^{m^3}/_{min} ✓$

$$v_s = v_1 - v_c \Longrightarrow v_1 = 1,05v_s ✓\ and$$

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

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

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

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

$$p_3 v_3 = mRT_3 \Longrightarrow v_3 = \frac{4,5 \times 0,287 \times 288}{3 \times 101,3 \times 300} = 4,08 \times 10^{-3} m^3 ✓$$

$$\eta_{vol} = \frac{v_{ind}}{v_s} ✓ \Longrightarrow v_s = \frac{4,08\times10^{-3}}{0,934} = 4,37 \times 10^{-3} m^3 ✓$$ (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

$$h_c = h_f + xh_{fg} = 640 + 0{,}96 \times 2107\checkmark = 2662{,}72\ {}^{kJ}/_{kg}\ \checkmark$$

$$h_1 = h_g = 2773\ {}^{kJ}/_{kg}\ \checkmark$$

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

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

2.2.2

$$h_2 = h_f + x_{2a}h_{fg} = 584 + 0{,}945\checkmark \times 2147 = 2612{,}915\ {}^{kJ}/_{kg}\ \checkmark$$

$$H_2 = mh_2 = 0{,}645 \times 2612{,}915\checkmark = 1685{,}33\ kJ\checkmark$$

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

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

$$\eta_{noz} = \frac{h_1 - h_2}{h_1 - h_{2s}}\checkmark = \frac{2773 - 2612{,}915}{2773 - 2578{,}563} = 0{,}8233\checkmark$$ (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:

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

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

3.2.1 $\beta = 26°$ (1)

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

3.2.3 $$\eta_{dia} = \frac{2U(\Delta V_w)}{V_1^{\,2}}\checkmark = \frac{2 \times 117{,}8097(1040 + 424)}{700^2}\checkmark = 70{,}4\%\checkmark$$ (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 $h_1 = 101\ {}^{kJ}/_{kg}$✓; $h_2 = 351\ kJ/kg$✓

$$Q_{eco} = \frac{m_s}{m_f}(h_2 - h_1)\checkmark \Longrightarrow \frac{m_s}{m_f} = \frac{2100}{351 - 101} = 8{,}4\ {}^{kg_s}/_{kg_f}\ or\ 8{,}4\checkmark$$ (4)

4.2.2 $h_4 = h_g + c_p(t_{sup} - t_s) = 2802 + 3{,}1125(305 - 242{,}5)$✓

$= 2996{,}53\ {}^{kJ}/_{kg}$ ✓

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

4.2.3 $h_3 = h_g + xh_{fg}$

$= 1050 + 0{,}9787 \times 1752$✓

$= 2764{,}68\ {}^{kJ}/_{kg}$ ✓

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

$Q_{sup} = \frac{m_s}{m_f}(h_4 - h_3) = 8{,}4(2996{,}53 - 27764{,}68) = 1947{,}54\ {}^{kJ}/_{kg}$ ✓

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

$= 18 \times 1{,}005(119 - 25)$✓

$= 1700{,}46\ {}^{kJ}/_{kg}$ ✓ (6)

4.2.4 $Q_{chim} = m_g c_{pg}(t_{out} - t_{in})$

$= 19 \times 1{,}07(177{,}09 - 25)$✓

$= 3091{,}99\ {}^{kJ}/_{kg}$ ✓

$\% = \frac{Q_{chim}}{CV} = \frac{3091{,}99}{32000} \times 100 = 9{,}66\%$✓ (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 $P_b = 0{,}5p_b \times AlNn$✓

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

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

5.2.2 $sfc_b = \frac{m}{P_b}$✓ $\Longrightarrow m = 0{,}226 \times 146{,}689$✓ $= 33{,}152\ kg/h$✓ (3)

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

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

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

$and\ flow\ rate, v_s = 720 \times 20{,}615 \times 10^{-3} = 14{,}843\ {}^{m^3}/_{min}$ ✓

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

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

$= 11{,}294\ {}^{m^3}/_{min}$ ✓

$\eta_{vol} = \frac{v_{ind}}{v_s}$✓ $= \frac{11{,}294}{14{,}843} = 0{,}761$✓ (7)

[20]

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QUESTION 6

6.1

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

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

6.2

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

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

6.3

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

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

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

6.4

$$Q_{in} = mc_p(T_3 - T_2) = 10 \times 1,03(1143 - 550)\checkmark = 6107,9\ kJ/s\checkmark$$

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

6.5

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

[20]

TOTAL: 100

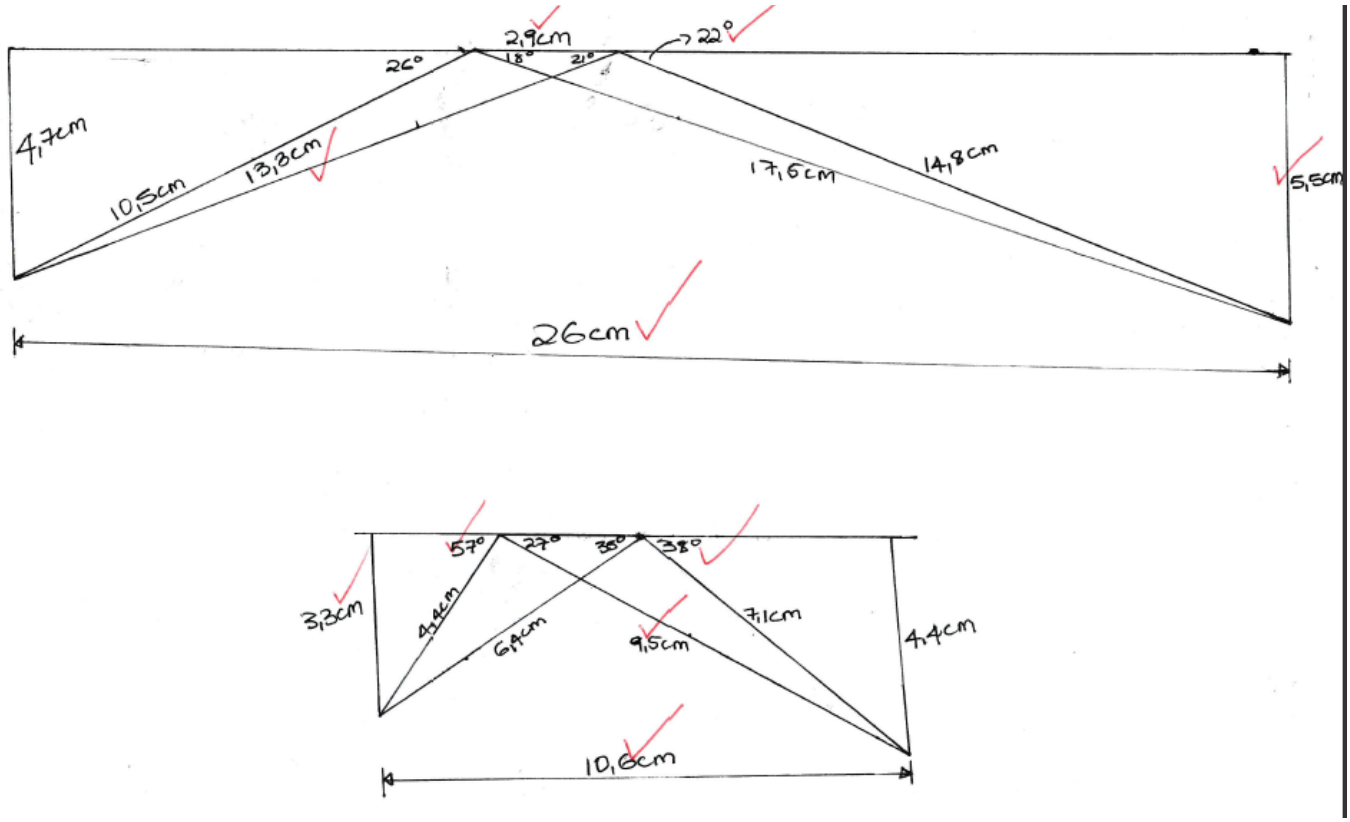


FIGURE 1

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