higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES N6

13 August 2021

This marking guideline consists of 9 pages.

Copyright reserved

QUESTION 1

1.1 $T_c = T_1\left(\frac{2}{\gamma+1}\right)$ ✓

$\Rightarrow\ 386 = 463\left(\frac{2}{\gamma+1}\right)$ ✓

$\therefore\ \gamma = 1{,}398\,964 \approx 1{,}4$ ✓

1.2 $R = C_p - C_v$ and $\gamma = \frac{C_p}{C_v}$; solve simultaneously:

$\Rightarrow C_p = \frac{\gamma R}{\gamma - 1}$ ✓

$= \frac{1{,}4 \times 0{,}298}{1{,}4 - 1}$ ✓

$= 1{,}043\ \text{kJ/kg. K}$ ✓

1.3 $\frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^{\frac{\gamma}{\gamma-1}}$ ✓

$$P_1 = 103\left(\frac{463}{252{,}5}\right)^{\frac{1{,}4}{1{,}4-1}}$$ ✓

$$P_1 = 859{,}916\ \text{kPa}$$ ✓

1.4 $P_c = P_1\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$ ✓

$$P_c = 859{,}916\left(\frac{2}{1{,}4+1}\right)^{\frac{1{,}4}{1{,}4-1}}$$ ✓

$$P_c = 454{,}278\ \text{kPa}$$ ✓

1.5 $C_2 = \sqrt{2\,000\ C_p(T_1 - T_2) + C_1^2}$ ✓

$= \sqrt{2\,000 \times 1{,}043(463 - 252{,}5) + 0}$ ✓

$= 662{,}648\ \text{m/s}$ ✓

Copyright reserved

1.6 $\text{Ma} = \frac{C_2}{C_c}$ ✓

$$\Rightarrow\ 1{,}653 = \frac{662{,}648}{C_c}\ ✓$$

$$\therefore\ C_c = 400{,}876\ \text{m/s}✓$$

OR

$$C_c = \sqrt{2\,000 C_p (T_1 - T_c) + C_1^2}$$

$$= \sqrt{2\,000 \times 1{,}043(463 - 386) + 0}$$

$$= 400{,}777\ \text{m/s}$$

(6 × 3) (18)

1.7 $EK_2 = \frac{1}{2} \times \dot{m} \times C_2^2$

$$= \frac{1}{2} \times 5 \times 662{,}648^2 \times 10^{-6}✓$$

$$= 1{,}098\ \text{MW}✓$$

(2)
[20]

QUESTION 2

2.1 2.1.1 $BP = \frac{2\pi NT}{60}$

$$BP = \frac{2\pi N \times Fr}{60}✓$$

$$= \frac{2\pi \times 390 \times 510 \times 0{,}57}{60} \times 10^{-3}✓$$

$$= 11{,}872\ \text{kW}✓$$

2.1.2 $IP = P_i LACE$✓

$$= 555 \times 0{,}34 \times \frac{\pi \times 0{,}18^2}{4} \times \frac{390}{2 \times 60} \times 1✓$$

$$= 15{,}606\ \text{kW}✓$$

2.1.3 $\eta_m = \frac{BP}{IP} \times 100$✓

$= \frac{11,872}{15,606} \times 100$✓

$= 76,073\%$✓

2.1.4 $FP = m_{f/s} \times CV$✓

$= \frac{0,06}{60} \times 43\,000$✓

$= 43\ kW$✓

2.1.5 $\eta_{b.th.} = \frac{BP}{FP} \times 100$✓

$= \frac{11,872}{43} \times 100$✓

$= 27,609\%$✓

(5 × 3) (15)

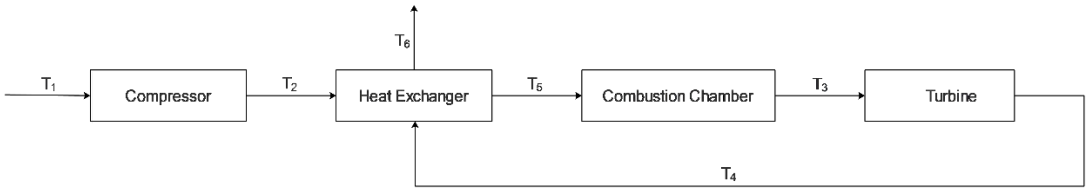
2.2

Heat flow	Details	kJ/s	%
From fuel	$m_{f/s} \times CV$	$\frac{0,06}{60} \times 43\,000 = 43$	100
To BP	2.1.1 above	11,872	27,609✓
To exhaust	34,8% of FP	$0,348 \times 43 = 14,964$	34,8
To coolant	$mc\Delta t$	$= \frac{4,5}{60} \times 4,187(59 - 17,5) = 13,032$✓	30,307✓
To radiation	Balance	$43 - 11,872 - 14,964 - 13,032 = 3,132$✓	7,284✓

(5)
[20]

QUESTION 3

3.1



For compressor:

$$T_{2i} = T_1\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \checkmark = 288(6)^{\frac{1,4-4}{1,4}} = 480,531\ K\checkmark$$

$$\eta_c = \frac{T_{2i} - T_1}{T_2 - T_1}\checkmark$$

$$T_2 = T_1 + \frac{T_{2i} - T_1}{\eta_c} = 288 + \frac{480,531 - 288}{0,85} = 514,507\ K\checkmark$$

For turbine:

$$T_{4i} = T_3\left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}} \checkmark = 1\,143\left(\frac{1}{6}\right)^{\frac{1,4-1}{1,4}} = 685,042\ K\checkmark$$

$$\eta_t = \frac{T_3 - T_4}{T_3 - T_{4i}}\checkmark$$

$$T_4 = T_3 - \eta_t(T_3 - T_{4i}) = 1\,143 - 0,8(1\,143 - 685,042) = 776,634\ K\checkmark$$

$$P = \dot{m}C_p[(T_3 - T_4) - (T_2 - T_1)]\checkmark$$
$$= 4 \times 1,005[(1\,143 - 776,634) - (514,507 - 288)]$$
$$= 562,233\ kW\checkmark$$ (10)

3.2 Maximum temperature drop available for heat transfer:

$$T_4 - \Delta T_i = T_2 + \Delta T_i$$
$$\therefore T_4 - T_2 = 2\Delta T_i$$
$$\Delta T_i = \frac{T_4 - T_2}{2} = \frac{776,634 - 514,507}{2} = 131,064\ °C\checkmark$$

Actual temperature drop $= k \times \Delta T_i = 0,65 \times 131,064 = 85,192\ °C\checkmark$

Exhaust temperature from heat exchanger: $T_6 = T_4 -$ actual temperature drop
$= 776,634 - 85,192 = 691,442\ °C\checkmark$

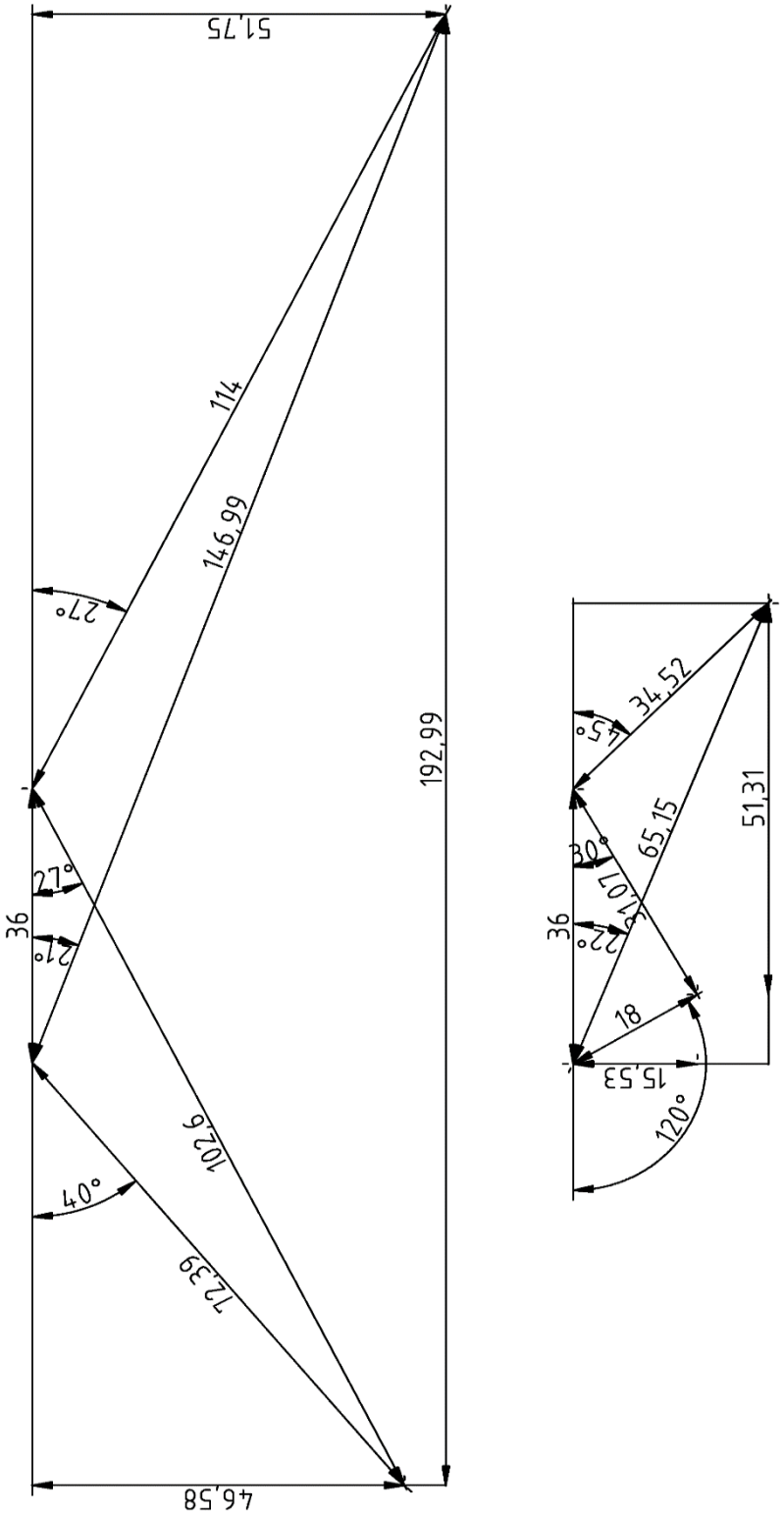
Temperature before combustion: $T_5 = T_2 +$ actual temperature drop
$= 514,507 + 85,192 = 599,699°C\checkmark$ (4)

3.3 $$\eta_{th} = \frac{(T_3 - T_4) - (T_2 - T_1)}{(T_3 - T_5)} \times 100\checkmark$$
$$= \frac{(1\,143 - 776{,}634) - (514{,}507 - 288)}{(1\,143 - 599{,}699)} \times 100\checkmark$$
$$= 25{,}742\%\checkmark$$ (3)

3.4 $$\eta_{th} = \frac{(T_3 - T_4) - (T_2 - T_1)}{(T_3 - T_2)} \times 100\checkmark$$
$$= \frac{(1\,143 - 776{,}634) - (514{,}507 - 288)}{(1\,143 - 514{,}507} \times 100\checkmark$$
$$= 22{,}253\%\checkmark$$ (3)
[20]

QUESTION 4

4.1 $U = \frac{\pi DN}{60} = \frac{\pi \times 1{,}35 \times 2\,546{,}5}{60} = 180 \text{ m/s}$✓



Award ½ mark for each correct length or angle, up to a maximum of 4½ marks per stage.
A tolerance of ± 2 mm may be allowed for lengths and a tolerance of ± 1° may be allowed for angles. (10)

4.2 4.2.1 $\beta_1 = 40°$ (1)

4.2.2 $\alpha_2 = 22°$ (1)

4.2.3 $V_2 = 72{,}39 \times 5 = 361{,}95\ m/s$ (1)

4.2.4 $V_4 = 18 \times 5 = 90\ m/s$ (1)

4.2.5 $P = \dot{m}UV_{WT}$✓
$= 21 \times 180 \times (192{,}99 \times 5 + 51{,}31 \times 5)$✓
$= 4\ 617\ 270\ W$
$= 4{,}617\ MW$✓ (3)

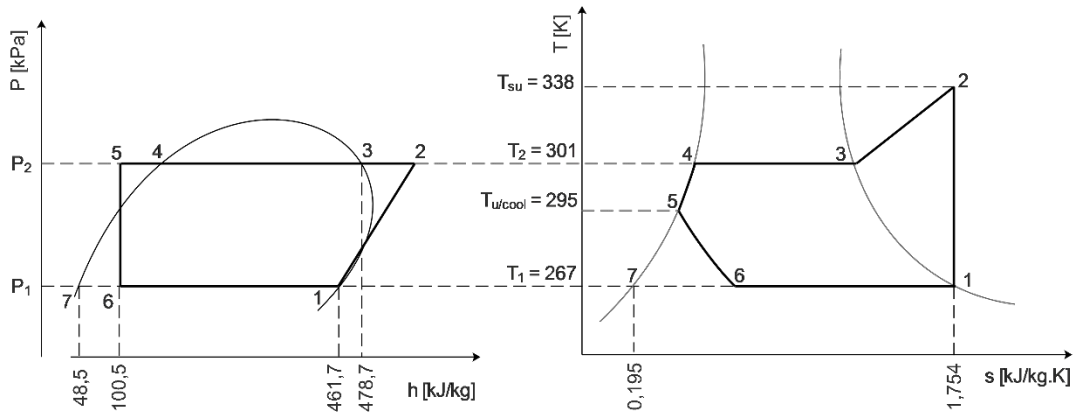
4.2.6 $\eta_{blading} = \frac{2UV_{WT}}{V_1^2} \times 100$✓

$= \frac{2 \times 180 \times (192{,}99 \times 5 + 51{,}31 \times 5)}{(146{,}99 \times 5)^2} \times 100$✓

$= 81{,}41\%$✓ (3)
[20]

QUESTION 5

5.1



$h_2 = h_{sup} = h_g + C_p(T_{su} - T_2)$√

$= 478{,}7 + 1{,}62(338 - 301)$√

$= 538{,}64\ kJ/kg$✓ (2)

5.2 $h_6 = h_w = h_7 + x_6(h_1 - h_7)$√

$100{,}5 = 48{,}5 + x_6(461{,}7 - 48{,}5)$√

$x_6 = 0{,}126$✓ (2)

5.3 $s_6 = s_7 + x_6(s_1 - s_7)\surd$

$= 0{,}195 + 0{,}126(1{,}754 - 0{,}195)\surd$

$= 0{,}391\ \text{kJ/kg.K}\checkmark$ (2)

5.4 $\dot{V}_e = \dot{m}_r \times V_g\surd$

$= 88 \times 0{,}2\surd$

$= 17{,}6\ \text{m}^3/\text{h}\checkmark$ (2)

5.5 $V_e = \frac{\dot{V}_e}{60 \times N}\surd$

$= \frac{17{,}6}{60 \times 310}\surd$

$= 0{,}000\ 946\ \text{m}^3\checkmark$

$\eta_{vol} = \frac{V_e}{V_s} \times 100\surd$

$= \frac{0{,}000\ 946}{1\ 150 \times 10^{-6}} \times 100\surd$

$= 82{,}261\%\checkmark$ (4)

5.6 $P_{compr.} = P_{1-2} = \dot{m}_r(h_2 - h_1)\checkmark$

$= \frac{88}{3\ 600}(538{,}64 - 461{,}7)\checkmark$
$= 1{,}88\ \text{kJ/s} = 1{,}88\ \text{kW}\checkmark$ (3)

5.7 $RE = m_r(h_1 - h_6)\checkmark$

$= \frac{88}{3\ 600}(461{,}7 - 100{,}5)\checkmark$

$= 8{,}829\ \text{kJ/s}\checkmark$ (3)

5.8 $COP = \frac{RE}{W_d} = \frac{RE}{P_{compr.}}\surd$
$= \frac{8{,}829}{1{,}88}\surd$
$= 4{,}697\checkmark$ (2)
[20]

TOTAL: 100

Copyright reserved