higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES

9 APRIL 2018

This marking guideline consists of 9 pages.

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QUESTION 1

1.1
- Carbon dioxide (CO_2)
- Sulphur dioxide (SO_2)
- Water(moisture) (H_2O) (3 × 2) (6)

1.2
- It converts steam into condensate at the same temperature.
- It creates a preservative vacuum.
- It creates a region of low pressure into which steam is exhausted.
- It saves water for recycling. (Any 2 × 2) (4)

[10]

QUESTION 2

Given:

P_1 = 95 kPa P_2 = 650 kPa R = 0,287 kJ/kg.K
V_1 = 1,25 m^3 $T_1 = (38 + 273) = 311\ K$

2.1 *Mass of air*

$$P_1V_1 = mRT_1 \quad \checkmark$$

$$m = \frac{P_1V_1}{RT_1} \quad \checkmark$$

$$= \frac{95 \times 1,25}{0,287 \times 311} \quad \checkmark$$

$$= 1,33 \quad kg \quad \checkmark$$

(4)

2.2

$$\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$$

$$P_1V_1^{1,24} = P_2V_2^{1,24} \quad or \quad \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} = \frac{V_1}{V_2}$$

$$V_2 = \left(\frac{P_1}{P_2}\right)^{1/1,24} V_1$$

$$= 1,25\left(\frac{95}{650}\right)^{1/1,24}$$

$$= 0,265\ m^3 \quad \checkmark$$

$$V_2 = \frac{1,25}{\left(\frac{650}{95}\right)^{\frac{1}{1,24}}} \quad \checkmark$$

$$= \frac{1,25}{4,716} \quad \checkmark$$

$$= 0,265\ m^3 \quad \checkmark$$

(3)

2.3 $P_2V_2 = mRT_2$ ✓

$$T_2 = \frac{P_2V_2}{mR}$$ ✓

$$= \frac{650 \times 0,265}{1,33 \times 0,287}$$ ✓

$$= 451,26\ K$$ ✓ (4)

2.4 *Work done during compression*

$$Workdone = \frac{P_1V_1 - P_2V_2}{n-1}$$

$$= \frac{(95 \times 1,25) - (650 \times 0,265)}{1,24 - 1}$$

$$= \frac{118,75 - 172,25}{0,24}$$

$$= -223kJ\ (negative\ sign\ indicates\ compression\ work\ done)$$ (4)

[15]

QUESTION 3

Given:

P = 2 500 kPa t_{in} = 32,9 °C t_{out} = 90 °C
Cv = 33 MJ/kg x = 0,95

3.1

$$Q = \frac{m_s}{m_f}(h_2 - h_1)$$ ✓

$$= \frac{5000}{650}(377 - 138)$$ ✓ ✓

$$= 1838,462\ kJ/kg$$ ✓

From S.T
at $32,9^oC$
$h_1 = 138kJ/kg$
at 90^oC
$h_2 = 377kJ/kg$ (4)

3.2 *At* $2500kPa$
$h_f = 962\ kJ/kg$
$h_{fg} = 1839\ kJ/kg$

$$h_3 = h_f + xh_{fg}$$

$$= 962 + (0,95 \times 1839)$$ ✓ ✓

$$= 2709,05kJ/kg$$ ✓

$$\eta = \frac{\dot{m}_s(h_3 - h_1)}{\dot{m}_f \times CV} \times 100$$ ✓ ✓

$$= \frac{5000}{650} \frac{(2709,05 - 138)}{33000} \times 100$$ ✓

$$= 59,93\%$$ ✓ (7)

3.3 *The equivalent evaporator (EE) at 100 °C*

$$EE = \frac{\dot{m}_s(h_3 - h_1)}{\dot{m}_f \times 2257} \quad \checkmark\checkmark$$

$$= \frac{5\,000(2709{,}05 - 138)}{650 \times 2257} \quad \checkmark$$

$$= 8{,}763\ kg/kg \quad \checkmark$$

(4)
[15]

QUESTION 4

Given:

B_m = 755 mmHg SHC_w = 4,187 kJ/kg.K t_{wi} = 15 °C m_s = 200 kg
M_m = 650 mmHg t_c= 45,8 °C t_{wo} = 23 °C

4.1 *Absolute pressure*

$$p = (B_m - M_m)\frac{101{,}325}{760}$$

$$= (755 - 650)\frac{101{,}325}{760} \quad \checkmark\checkmark$$

$$= 14\ kPa \quad \checkmark$$

(3)

4.2 $h_s = xh_{fg}$ *From S.T at 14kPa*

$= 0{,}9 \times 2377$ $h_{fg} = 2377\ kJ/kg$ ✓

$= 2139{,}3\ kJ/kg$ ✓ $x = (1 - 0{,}1) = 0{,}9$

$h_c = 4{,}187(ts - tc)$

$= 4{,}187(52{,}6 - 45{,}8)$ ✓✓

$= 28{,}472 kJ/kg$ ✓

heat lost by steam and condensate = heat gained by the cooling water

$$m_s(h_s + h_c) = mC_P(t_{out} - t_{in}) \quad \checkmark$$

$$200(2139{,}3 + 28{,}472) = m \times 4{,}187 \times (23 - 15) \quad \checkmark$$

$$\frac{200 \times 2167{,}772}{4{,}187 \times 8} = m$$

$$m = 12943{,}47\ kg/\min \quad \checkmark$$

(9)

4.3 $\log temperature\ difference$

$$\log temp\ diff = \frac{\theta_1 - \theta_2}{\ln\frac{\theta_1}{\theta_2}}$$

$$\theta_1 = t_c - twi$$

$$\theta_1 = 45{,}8 - 15 = 30{,}8$$

$$= \frac{30{,}8 - 22{,}8}{\ln\frac{30{,}8}{22{,}8}} \quad \checkmark$$

$$\theta_2 = t_c - t_{wo} \quad \checkmark$$

$$\theta_2 = 45{,}8 - 23 = 22{,}8$$

$$= 26{,}6\ ^\circ C \quad \checkmark$$

(3)
[15]

QUESTION 5

5.1

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 = xCO_2 + \frac{y}{2}H_2O$$

$$x = 7 \quad y = 18$$

$$C_7H_{18} + \left(7 + \frac{18}{4}\right)O_2 = 7CO_2 + \frac{18}{2}H_2O$$

$$[(12 \times 7) + (1 \times 18)] + (11{,}5 \times 2 \times 16) = 7[(12 + 2 \times 16)] + 9[(1 \times 2) + 16] \quad \checkmark$$

$$(84 + 18) + 368 = 308 + 162 \quad \checkmark$$

$$102 + 368 = 308 + 162\ (divide\ through\ by\ 102)$$

$$1 + 3{,}608 = 3{,}02 + 1{,}588 \quad \checkmark$$

$$Theorectical\ mass\ of\ air\ required = \frac{100}{23} \times mass\ O_2$$

$$= \frac{100}{23} \times 3{,}608 \quad \checkmark$$

$$= 15{,}687\ kg \quad \checkmark$$

(5)

5.2

$$Actual\ mass\ of\ air\ required = \frac{100 + x}{100} \times theorectical\ mass\ of\ air$$

$$= \left(\frac{100 + 40}{100}\right) \times 15{,}687\ kg \quad \checkmark$$

$$= 21{,}962\ kg \quad \checkmark$$

OR

$$(\%\ Excess\ air \times theorectical\ mass\ of\ air) + theorectical\ mass\ of\ air$$

$$= (0{,}4 \times 15{,}687) + 15{,}687 \quad \checkmark$$

$$= 21{,}962\ kg/kg \quad \checkmark$$

(2)

5.3 Mass of each product of combustion

SYMBOL	MASS
CO_2	$3,02\ kg$ ✓
H_2O	$1,588\ kg$
Excess O_2	$0,40 \times 3,608 = 1,443\ kg$ ✓
N_2	$0,77 \times 21,962 = 16,911\ kg$ ✓
TOTAL	$\underline{22,962kg}$ ✓

(4)

5.4 % of each mass of combustion

SYMBOL	% BY MASS
CO_2	$\frac{3,02}{22,962} \times 100 = 13,31\%$ ✓
H_2O	$\frac{1,588}{22,962} \times 100 = 6,92$ ✓
O_2	$\frac{1,443}{22,986} \times 100 = 6,28$ ✓
N_2	$\frac{16,911}{22,962} \times 100 = 73,65$ ✓
TOTAL	100%

(4)
[15]

QUESTION 6

Given:

P_1 = 103 kPa t_1 = 22 °C + 273 = 295 K $V_2 = \frac{V_1}{6}$

P_2 = 900 kPa R = 0,287 kJ/kg.K

6.1
$$P_1V_1^n = P_2V_2^n$$
$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^n$$
$$\log\frac{900}{103} = n \log\left(\frac{V_1}{\frac{1}{6}V_1}\right) \checkmark \quad or \quad \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$$
$$\left(\frac{P_2}{P_1}\right) = \left(\frac{V_1}{V_2}\right)^n$$
$$n = \frac{\log\frac{900}{103}}{\log 6} \checkmark$$
$$= 1,21 \checkmark$$

(5)

6.2

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} \quad \checkmark$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} \quad \checkmark$$

$$= 295\left(\frac{900}{103}\right)^{\frac{0,21}{1,21}}$$

$$= 429,7K \quad \checkmark$$

(3)

6.3 *Volume after compression*

$$P_2V_2 = mRT_2 \quad \checkmark$$

$$V_2 = \frac{mRT_2}{P_2}$$

$$= \frac{1 \times 0,287 \times 429,74}{900} \quad \checkmark$$

$$= 0,137\ m^3 \quad \checkmark$$

OR

$$P_1V_1 = mRT_1$$

$$V_1 = \frac{mRT_1}{P_1}$$

$$= \frac{1 \times 0,287 \times 295}{103}$$

$$= 0,822\ m^3 \quad \checkmark$$

$$V_2 = \frac{V_1 1}{6} \quad \checkmark$$

$$= \frac{0,822}{6}$$

$$= 0,137\ m^3 \quad \checkmark$$

(3)

6.4 *Work done after compression*

$$Work\ done = \frac{n}{n-1}P_1V_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \left(\frac{1,21}{1,21-1}\right)\times 103 \times 0,822\left[\left(\frac{900}{103}\right)^{\frac{0,21}{1,21}} - 1\right] \quad \checkmark \quad \checkmark$$

$$= 487,84 \times 0,822$$

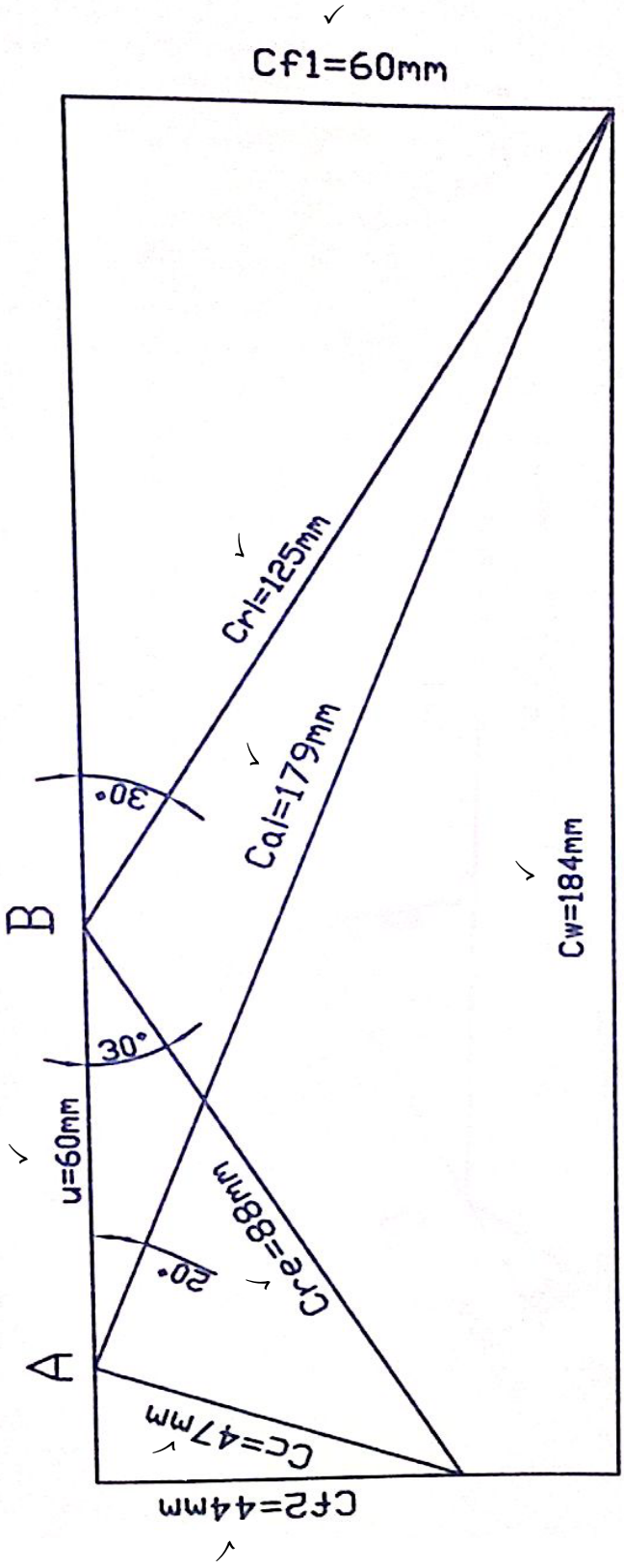
$$= 222,82kJ \quad \checkmark$$

(4)

[15]

QUESTION 7

7.1



(8)

7.2 7.2.1 Cri = 125 × 5 = 625 m/s (1)

7.2.2 Cre = 88 × 5 = 440 m/s (1)

7.2.3 $$\begin{aligned} The\ axial\ thrust &= m(C_{f1} - C_{f2}) \\ &= 1 \times \left[(60 \times 5) - (44 \times 5)\right] \\ &= 1 \times (16 \times 5) \\ &= 80\ N \end{aligned}$$ (2)

7.2.4 $$\begin{aligned} \eta &= \frac{2U\ C_w}{C_{ai}^{\ 2}} \times 100 \\ &= \frac{2 \times 300 \times (184 \times 5)}{(179 \times 5)^2} \times 100 \\ &= \frac{2 \times 300 \times 920}{(895)^2} \times 100 \\ &= 68{,}9\% \end{aligned}$$ (3)

[15]

TOTAL: 100

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