

# higher education & training

Department:  
Higher Education and Training  
**REPUBLIC OF SOUTH AFRICA**

## **MARKING GUIDELINE**

**NATIONAL CERTIFICATE**

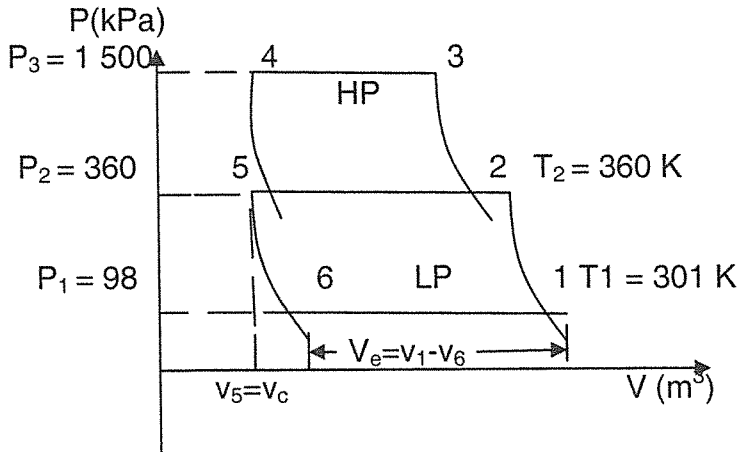
**APRIL EXAMINATION**

**POWER MACHINES N6**

**2 APRIL 2015**

**This marking guideline consists of 10 pages.**

QUESTION 1



Incomplete intercooling:

1.1

$$P = \frac{nmRT_1}{n-1} \left[ \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right] + \frac{nmRT_2}{n-1} \left[ \left( \frac{P_3}{P_2} \right)^{\frac{n-1}{n}} - 1 \right]$$

$$= \frac{1.3 \times 3 \times 0.288 \times 301}{0.3 \times 60} \left[ \left( \frac{360}{98} \right)^{\frac{0.3}{1.3}} - 1 \right] + \frac{1.3 \times 3 \times 0.288 \times 360}{0.3 \times 60} \left[ \left( \frac{1500}{360} \right)^{\frac{0.3}{1.3}} - 1 \right]$$

$$= 6,5778 + 8,76 = 15,338 \text{ kW}$$

$$P_{req} = \frac{15,338}{0.85} = 18,04 \text{ kW} \tag{7}$$

1.2

$$V_e = \frac{mRT_1}{P_1} = \frac{3 \times 0.288 \times 301}{2 \times 240 \times 98} = 0,005528 \text{ m}^3/\text{stroke}$$

$$V_{s1} = \frac{V_e}{\eta} = \frac{0,005528}{0,92} = 0,006 \text{ m}^3$$

$$V_{s1} = \frac{\pi d^2 L}{4} = \frac{\pi d^2 \times 1,5d}{4}$$

$$0,006 = 1,17809 \times d^3 \tag{7}$$

$d = 0,172 \text{ m} = 172 \text{ mm}$

1.3

$$T_2 = T_1 \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} = 301 \left( \frac{360}{98} \right)^{\frac{0.3}{1.3}} = 406,4 \text{ K}$$

$$Q_{1-2} = \frac{mR(T_1 - T_2)}{n-1} + mC_v(T_2 - T_1) \quad \& \quad C_v = C_p - R = 1,005 - 0,288 = 0,717 \text{ kJ/kg.K}$$

$$= \frac{3 \times 0,288(301 - 406,4)}{2 \times 240 \times 0,3} + \frac{3 \times 0,717(406,4 - 301)}{2 \times 240}$$

$$= -0,6324 + 0,472 = -0,1604 \text{ kJ} \tag{6}$$

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## QUESTION 2

2.1 From steam table: @ 3 000 kPa :  $h_f = 1\,008$  kJ/kg  
 $h_{fg} = 1\,794$  kJ/kg  
 $h_c = 184$  kJ/kg  $h_e = 741$  kJ/kg  $h_s = 2\,858$  kJ/kg

$$h_b = h_f + xh_{fg} = 1\,008 + 0,98 \times 1\,794 = 2\,766 \text{ kJ/kg}$$

$$Q_{EC} = m_s (h_e - h_c) = 9,5 (741 - 184) = 5\,291,5 \text{ kJ}$$

$$Q_b = m_s (h_b - h_e) = 9,5 (2\,766 - 741) = 19\,237 \text{ kJ}$$

$$Q_{sh} = m_s (h_s - h_b) = 9,5 (2\,858 - 2\,766) = 874 \text{ kJ}$$

$$Q_{ah} = m_a \cdot C_p \cdot \Delta t = 20 \times 1,005 \times (150 - 15) = 2713 \text{ kJ} \quad (10)$$

2.2 
$$\eta = \frac{m_s (h_s - h_c)}{m_f \times C_v}$$

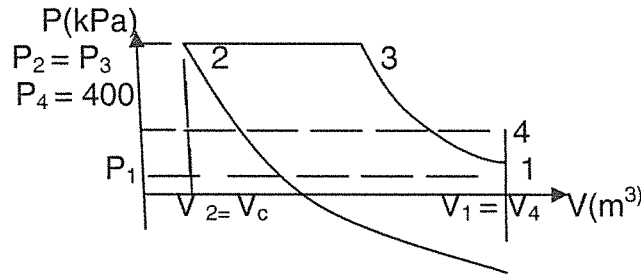
$$= \frac{9,5 (2858 - 184)}{1 \times 31800}$$

$$= 79,88\% \quad (4)$$

2.3 Heat to flues = heat Supplied - Heat absorbed.  
 $m \times C_p \times \Delta t = CV - M_s (h_s - h_c) + m_a \times C_{p_a} \times \Delta t_a$   
 $21 \times 1,045 (t_{exh} - 15) = 31\,800 - 9,5 (2\,858 - 184) + 20 \times 1,005 \times 15$   
 $t_{exh} = \frac{6698,5}{21,945} + 15$   
 $= 320,24 \text{ }^\circ\text{C} \quad (6)$

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QUESTION 3



3.1 
$$V_s = \frac{\pi d^2 L}{4} = \frac{\pi (0,18)^2 \times 0,25}{4} = 0,00636 \text{ m}^3$$
  

$$V_1 = V_s + V_c = 0,00636 + 0,00041 = 0,00677 \text{ m}^3 \tag{4}$$

3.2 
$$V_3 = V_2 + \frac{20}{250} \cdot V_s = 0,00041 + \frac{20}{250} \times 0,00636$$
  

$$= 0,00092 \text{ m}^3 \tag{3}$$

3.3 
$$P_3 = P_4 \left( \frac{V_4}{V_3} \right)^{\gamma} = 400 \left( \frac{0,00677}{0,00092} \right)^{1,28}$$
  

$$= 5147,13 \text{ kPa}$$
  

$$P_1 = P_2 \left( \frac{V_2}{V_1} \right)^{\gamma} = 5147,13 \left( \frac{0,00041}{0,00677} \right)^{1,35} = 116,82 \text{ kPa} \tag{4}$$

3.4 
$$\text{WD/Cycle} = P_2 (V_3 - V_2) + \frac{P_3 V_3 - P_4 V_4}{\gamma - 1} - \frac{P_2 V_2 - P_1 V_1}{\gamma - 1}$$
  

$$= 5147,13 (0,00092 - 0,00041) + \frac{5147,13 \times 0,00092 - 400 \times 0,00677}{0,28} - \frac{5147,13 \times 0,00041 - 116,82 \times 0,00677}{0,35}$$
  

$$= 2,625 + 7,2406 - 3,76986$$
  

$$\therefore \text{WD/Cycle} = 6,096 \text{ kJ} \tag{5}$$

3.5 
$$\text{IP} = \text{WD /Cycle} \times \text{Cycle/second}$$
  

$$= 6,096 \times \frac{330}{60} \times 4$$
  

$$= 134,11 \text{ kW} \tag{4}$$
  

**[20]**

**QUESTION 4**

4.1  $\Delta IP_1 = 56 - 44,2 = 11,8 \text{ kW}$   
 $\Delta IP_2 = 56 - 44 = 12 \text{ kW}$   
 $\Delta IP_3 = 56 - 43,9 = 12,1 \text{ kW}$   
 $\Delta IP_4 = 56 - 44,3 = 11,7 \text{ kW}$   
 $\Delta IP_5 = 56 - 44,1 = 11,9 \text{ kW}$   
 $\Delta IP_6 = 56 - 43,7 = 12,3 \text{ kW}$   
 $\Delta IP \text{ Total} = 71,8 \text{ kW}$

$$\eta = \frac{BP}{IP} \times 100\%$$

$$= \frac{56}{71,8} \times 100\% = 77,99\% \quad (7)$$

4.2  $m_f / \text{min} = \frac{ISFC \times IP}{60}$

$$= \frac{0,26 \times 71,8}{60} = 0,311 \text{ kg /min} \quad (2)$$

4.3  $m_{\text{exh}} / \text{min} = m_f / \text{min} \times (A / F + 1)$   
 $= 0,311 \times (15,2 + 1) = 5,038 \text{ kg/min} \quad (2)$

4.4  $Q_{\text{exh}} = m_{\text{exh}} \times C_p \times \Delta T$   
 $= 5,038 \times 1,1 (400 - 18) = 2116,97 \text{ kJ/min} \quad (2)$

4.5  $Q_w = m_w \cdot C_{p_w} \cdot \Delta T = 34 \times 4,187 \times 38 = 5409,6 \text{ kJ/min} \quad (2)$

4.6

Heat gained ((kJ/min)	Heat supplied (kJ/min)	Percentage
$Q = m_f \times C_v$ $= 0,311 \times 42000$ $= 13062$	BP = 56 x 60 = 3 360	25,72
	QW = 5 409,6	41,41
	Q <sub>exh</sub> = 2 116,97	16,21
	Unaccounted = 2 175,43	16,65
	TOTAL = 13 062	100

(5)  
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## QUESTION 5

5.1 (superheated tables) :  $h_1 = 2\,925$  kJ/kg @  
1 500 kPa and 250 °C

$$C_c = \sqrt{2000(h_1 - h_c)}$$

$$\therefore h_1 - h_c = \frac{C_c^2}{2000} = \frac{500^2}{2000} = 125 \text{ kJ/kg}$$

$$h_c = h_1 - 125 = 2\,925 - 125 = 2\,800 \text{ kJ/kg}$$

$$h_g = 2\,768 \text{ kJ/kg @ 820 kPa}$$

$$h_c = h_g + C_p (t_{\text{sup}} - t_s)$$

$$\therefore t_{\text{sup}} - t_s = \frac{h_c - h_g}{C_p} = \frac{2800 - 2768}{2,56} = 12,5 \text{ °C}$$

$$t_{\text{sup}} = t_s + 12,5 : (t_s = 171,4 \text{ °C @ 820 kPa})$$

$$= 171,4 + 12,5 = 183,9 \text{ °C}$$

(6)

5.2 
$$V_{\text{sup}} = \frac{n-1}{n} \left( \frac{h_c - 1941}{P_c} \right) = \frac{0,31}{1,31} \left( \frac{2800 - 1941}{820} \right)$$

$$= 0,2479 \text{ m}^3/\text{kg}$$

$$A_c = \frac{m v_c}{C_c} = \frac{5 \times 0,2479}{500} = 0,002479 \text{ m}^2$$

$$= 2479 \text{ mm}^2$$

$$A_c = \frac{\pi}{4} D_c^2 = 2479 = \frac{\pi}{4} D_c^2$$

$$\therefore D_c = 56,181 \text{ mm}$$

(6)

$$5.3 \quad X_2^1 = 0,9895. \quad X_2 = 0,94$$

$$\therefore X_2 = \frac{0,94}{0,9895} = 0,95$$

$$V_2 = X_2 \times V_g$$

$$= 0,95 \times 0,6684 = 0,635 \text{ m}^3/\text{kg}$$

$$A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4} (72,2)^2 = 4094,155 \text{ mm}^2$$

$$C_2 = \frac{mV_2}{A_2} = \frac{5 \times 0,635}{4094,155 \times 10^{-6}} = 775,5 \text{ m/s}$$

$$C_2 = \sqrt{2000(h_1 - h_2)}$$

$$h_1 - h_2 = \frac{(C_2)^2}{2000} = \frac{775,5^2}{2000} = 300,7 \text{ kJ/kg}$$

$$h_2 = h_1 - 300,7 = 2925 - 300,7 = 2624,3 \text{ kJ/kg}$$

$$(V_g = 0,6684, P = 270 \text{ kPa})$$

$$(h_f = 546 \text{ kJ/kg}, h_{fg} = 2174 \text{ kJ/kg @ 270 kPa})$$

$$h_2 = h_f + x h_{fg} = 546 + 0,95 (2174)$$

$$= 2611,3 \text{ kJ/kg}$$

$$C_2 = \sqrt{2000(h_1 - h_2)}$$

$$= \sqrt{(2000)(2925 - 2611,3)}$$

$$= 792 \text{ m/s}$$

$$A_2 = \frac{mV_2}{C_2} = \frac{5 \times 0,635}{792}$$

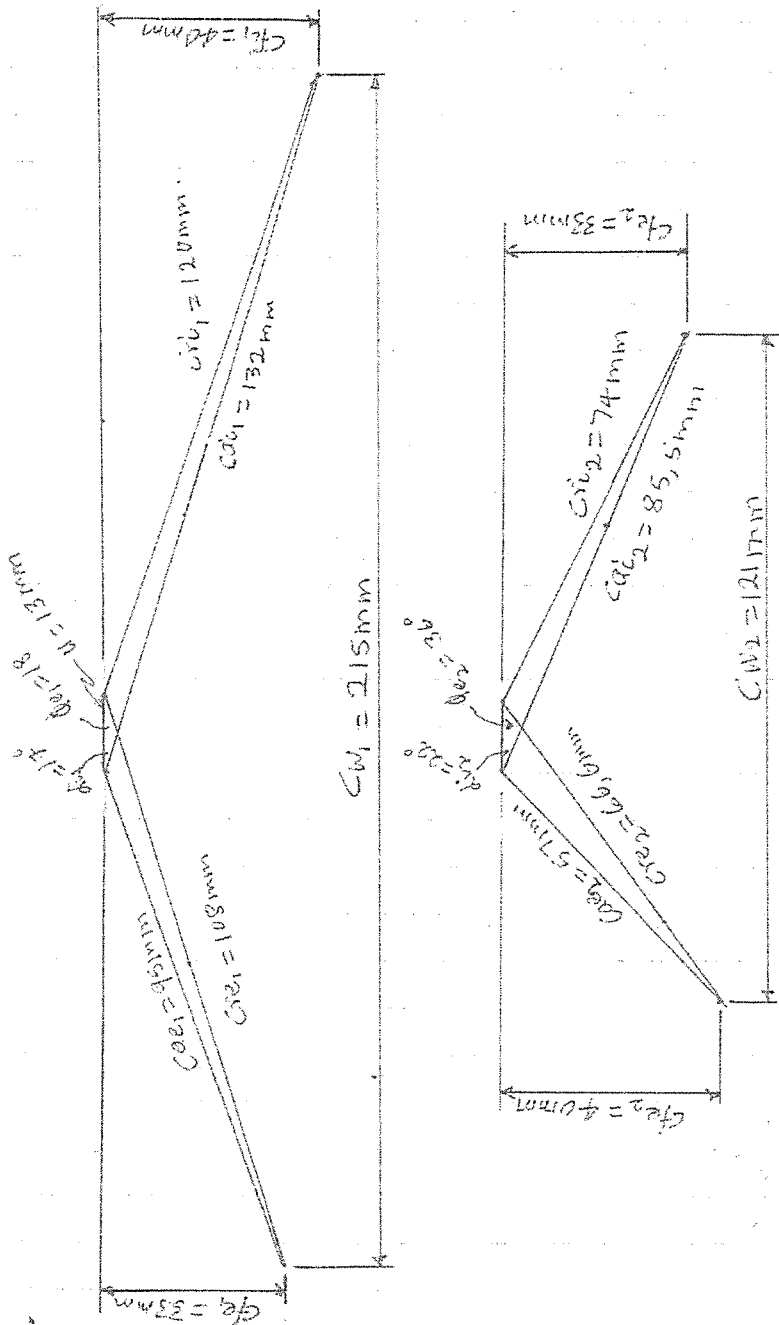
$$= 4008,4 \times 10^{-6} \text{ m}^2$$

$$= 4008,4 \text{ mm}^2$$

(8)  
[20]

QUESTION 6

6.1





$$6.2 \quad U = \pi \frac{D}{60} N = \pi \frac{(0,31) \times 4000}{60} = 64,9 \text{ m/s}$$

$$Cr_{e1} = kCr_{i1} = 0,9 \times 120 = 108 \text{ mm also } Cr_{e2} = kCr_{i2} = 0,9 \times 74 = 66,6 \text{ mm}$$

$$C_{ai2} = kC_{ae1} = 0,9 \times 95 = 85,5 \text{ mm}$$

$$6.2.1 \quad F_{\text{Axial}} = m(\Delta C_{f_i} - \Delta C_{f_e}) \\ = \frac{80(7-7) \times 5}{60} \\ = 0 \text{ N}$$

$$6.2.2 \quad F_{\text{Tang}} = m(\Delta C_{w_i} - \Delta C_{w_e}) \\ = \frac{80(215-121) \times 5}{60} \\ = 2\,240 \text{ N}$$

$$6.2.3 \quad P = F_{\text{Tang}} \times U \\ = 2\,240 \times 64,9 \\ = 145,38 \text{ kW}$$

$$6.2.4 \quad \eta = \frac{2U(\Delta C_{w_r})}{C_{ai}^2} \\ = \frac{2 \times 64,9(1075 + 605)}{660^2} \\ = 50,1\%$$

$$6.2.5 \quad U = 64,9 \text{ m/s}$$

(5 × 2) (10)  
[20]

**QUESTION 7**

$$7.1 \quad \text{Refrigerating effect} = (q_1 - q_2) \times h_{fg}$$

$$= (0,91 - 0,12) \times 1\,340$$

$$= 1\,058,6 \text{ kJ/kg}$$

$$\text{COP} = \frac{\text{Refrigerating effect}}{\text{Work done}}$$

$$= \frac{1058,6}{170}$$

$$= 6,23$$

(6)

$$7.2 \quad \text{Volume at suction} = 0,44 \times 5,6 \times 0,91$$

$$= 2,242 \text{ m}^3/\text{min}$$

$$\text{Volume of compressor} = \frac{\text{Volume at suction}}{\text{Volumetric efficiency}}$$

$$= \frac{2,242}{0,8}$$

$$= 2,803 \text{ m}^3/\text{min}$$

(7)

$$7.3 \quad \text{Volume/stroke} = \frac{\text{Volume of compressor}}{\text{Revs per minute}}$$

$$= \frac{2,803}{120} = 0,02\,336 \text{ m}^3$$

$$\text{Volume /stroke} = \frac{\pi D^2 L}{4} : L = D$$

$$0,02336 = \frac{\pi D^2 \times D}{4}$$

$$\therefore D^3 = 0,029741$$

$$D = \sqrt[3]{0,029741}$$

$$D = 0,31 \text{ m} = 310 \text{ mm}$$

(7)

[20]

**TOTAL: 100**