higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

NOVEMBER EXAMINATION

POWER MACHINES N6

21 NOVEMBER 2013

This marking guideline consists of 9 pages.

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QUESTION 1

1.1

$$BP = \frac{Q_{BP}}{60} = \frac{1680}{60} = 28\ kW$$

$$IP = \frac{Q_{BP}+Q_{FP}}{60} = \frac{1680+420}{60} = \frac{2100}{60} = 35\ kW$$

$$\eta_{mech} = \frac{BP}{IP} \times 100\% = \frac{28}{35} \times 100\% = 80\%$$

$$IP = \frac{P_i LACE}{60}$$

$$\therefore P_i = \frac{60 \times IP}{LA \times C \times E} = \frac{60 \times 35 \times 60 \times 2}{0{,}02 \times 21000} = 600\ kPa$$

$$P_i = \frac{A_d N_s}{L_d}$$

$$\therefore A_d = \frac{P_i \times L_d}{N_s} = \frac{76 \times 600}{80} = 570\ mm^2$$

(10)

1.2

$$Q_w = m_w Cp_w \Delta t_w$$

$$\therefore \Delta t_w = \frac{Q_w}{m_w Cp_w} = \frac{1176 \times 60}{350 \times 4{,}2} = 48°C$$

$$m_{f/h} = \frac{BP \times 60 \times 60}{\eta_{bt} \times CV} = \frac{28 \times 60 \times 60}{0{,}35 \times 45000} = 6{,}4\ kg/h$$

OR $m_{f/h} = \frac{Q_{f/h}}{CV} = \frac{4800 \times 60}{45000} = 6{,}4\ kg/h$

$$Q_{exh} = (m_a + 1) m_f \times Cp_g \Delta t_g$$

$$m_a = \frac{Q_{exh}}{m_f Cp_g \Delta t_g} - 1 = \frac{1320 \times 60}{6{,}4 \times 1{,}045 \times 382} - 1 = 31 - 1$$

$$= 30:1$$

(7)

1.3

$$Vs = \frac{\pi}{4} D^2 L = \frac{\pi}{4} D^2 \times 1{,}21D = \frac{1{,}21\pi}{4} D^3$$

$$D = \sqrt[3]{\frac{4Vs}{1{,}21\pi}} = \sqrt[3]{\frac{4 \times 0{,}02}{1{,}21\pi}} \times 10^3 = 276{,}09\ mm$$

$$L = 1{,}21D = 1{,}21 \times 276{,}09 = 334{,}069\ mm$$

(3)
[20]

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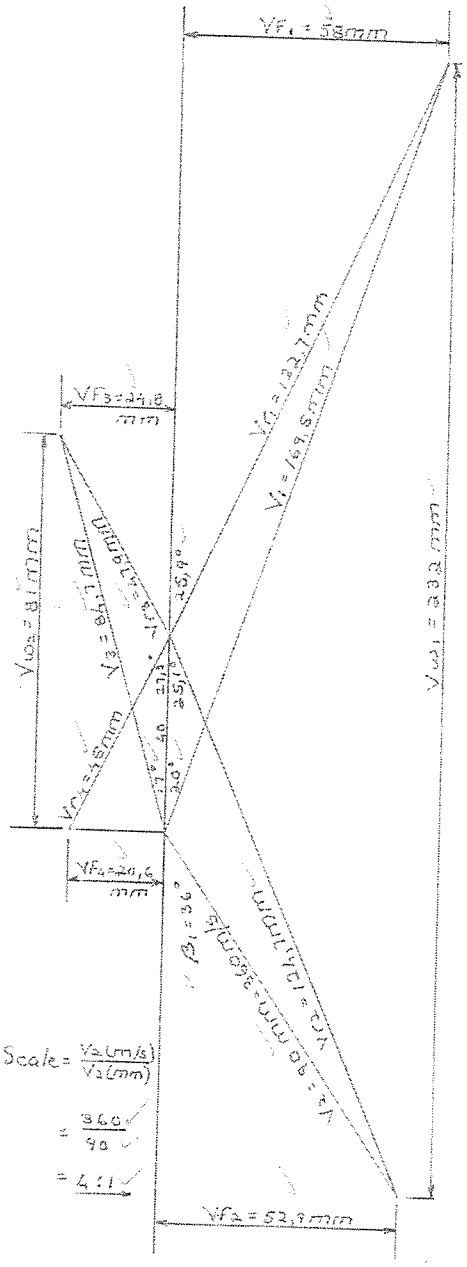
QUESTION 2

2.1



(10)

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2.2. 2.2.1 $\alpha_1 = 20^\circ$ ✓

2.2.2 $\theta_1 = 25,9^\circ$ ✓

2.2.3 $\theta_2 = 26,1^\circ$ ✓

2.2.4 $\theta_3 = 31,1^\circ$ ✓

2.2.5 $\theta_4 = 37,3^\circ$ ✓

2.2.6 $U = 40 \times 4 = 160 \text{ m/s}$ ✓

2.2.7 $V_1 = 169,6 \times 4 = 678 \text{ m/s}$ ✓

2.2.8 $V_3 = 84,7 \times 4 = 338,8 \text{ m/s}$ ✓

2.2.9 $V_4 = 20,6 \times 4 = 82,4 \text{ m/s}$ ✓

2.2.10 $F_{tang} = m(V_{w1} + V_{w3})$ ✓

$= 40(232 + 81)4$

$= 40(428 + 324)$

$= 40(-252) \times 10^{-3}$

$= 50,08 \text{ kW}$ ✓

$P = U \times F_{tang}$

$= 160 \times 50,08$

$= 8012,8 \text{ kW}$ ✓

(10)
[20]

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QUESTION 3

3.1

$$C_c = \sqrt{2000Cp(T_1 - T_c)} = \sqrt{2000 \times 1{,}005 \times 150} = 549{,}09\ m/s$$

$$T_1 - T_c = \Delta t$$
$$\therefore T_c = T_1 - \Delta t = 900 - 150 = 750\ K$$

$$T_c = T_1\left(\frac{2}{\gamma - 1}\right)$$
$$\therefore \gamma = \frac{2T_1}{T_c} - 1 = \frac{2 \times 900}{750} - 1 = 1{,}4$$

$$P_c = P_1\left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma+1}} = 2030\left(\frac{2}{2{,}4}\right)^{\frac{1{,}4}{0{,}4}} = 1072{,}412\ kPa$$

$$R = Cp - Cv \quad \text{and} \quad \gamma = \frac{Cp}{Cv}$$
$$\therefore R = Cp - \frac{Cp}{\gamma} = \frac{\gamma Cp - Cp}{\gamma} = \frac{Cp(\gamma - 1)}{\gamma} = \frac{1{,}005(0{,}4)}{1{,}4} = 0{,}287\ kJ/kg.K$$

$$V_c = \frac{RT_c}{P_c} = \frac{0{,}287 \times 750}{1072{,}412} = 0{,}200\ 7\ m^3/kg$$

$$A_c = \frac{mV_c}{C_c}$$
$$m = \frac{A_c C_c}{V_c} = \frac{1553{,}434 \times 549{,}09 \times 10^{-6}}{0{,}2007} = 4{,}25\ kg/s$$

(13)

3.2

$$C_2 = Mach\ No \times C_c = 1{,}3 \times 549{,}09 = 713{,}817\ m/s$$

$$C_2 = \sqrt{2000Cp(T_1 - T_2)}$$
$$T_2 = T_1 - \frac{{C_2}^2}{2000Cp} = 900 - \frac{713{,}817^2}{2000 \times 1{,}005} = 646{,}5\ K$$

$$T_2' = T_1\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = 900\left(\frac{598{,}9}{2030}\right)^{\frac{0{,}4}{1{,}4}} = 635\ K$$

$$\eta_{div} = \frac{T_c - T_2}{T_c - T_2'} = \frac{750 - 646{,}5}{750 - 635} = \frac{103{,}5}{115} \times 100\% = 90\%$$

(7)
[20]

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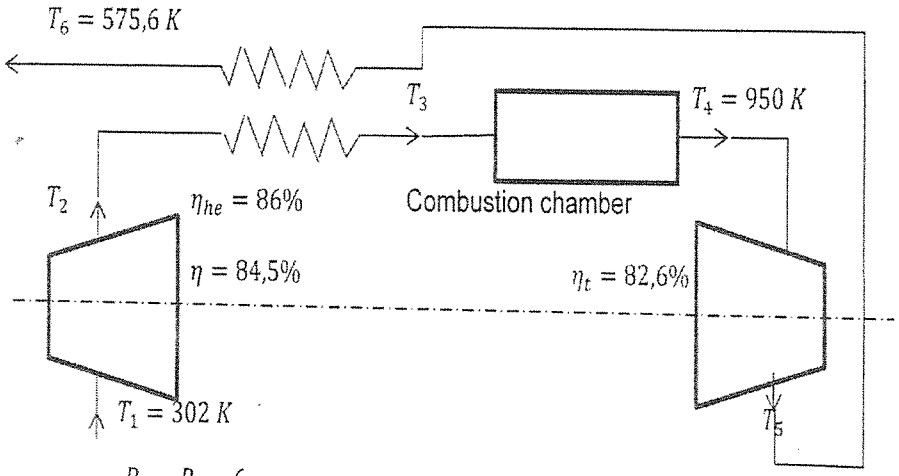
QUESTION 4



$m = 20\ kg/s;\ \frac{P_2}{P_1} = \frac{P_4}{P_3} = \frac{6}{1};\ \gamma = 1{,}4;\ Cp = 1{,}005\ kJ/kg.K$

4.1

$$T_2' = T_1\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = 302^{\checkmark}(6)^{\checkmark\frac{0,4}{1,4}} = 503{,}89\ K\checkmark$$

$$\eta_c = \frac{T_2'-T_1}{T_2-T_1}\checkmark$$

$$\therefore T_2 = T_1 + \frac{T_2'-T_1}{\eta_c} = 302\checkmark + \frac{503{,}89\checkmark-302\checkmark}{0{,}845\checkmark} = 302 + 238{,}923 = 540{,}923\ K\checkmark$$

$$P_c = mCp(T_2 - T_1) = 20 \times 1{,}005(540{,}923 - 302) = 4\,802{,}353\ kW\checkmark$$

(7)

4.2

$$T_5' = T_4\left(\frac{P_5}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = 950^{\checkmark}\left(\frac{1}{6}\right)^{\checkmark\frac{0,4}{1,4}} = 569{,}37\ K\checkmark$$

$$\eta_t = \frac{T_4-T_5}{T_4-T_5'}\checkmark \qquad \checkmark \quad \checkmark \quad \checkmark$$

$$\therefore T_5 = T_4 - \eta_t(T_4 - T_5') = 950 - 0{,}826(950 - 569{,}37) = 950 - 314{,}4 = 635{,}6\ K\checkmark$$

$$P_t = mCp(T_4 - T_5) = 20 \times 1{,}005(950 - 635{,}6) = 6\,319{,}44\ kW$$

(6)

4.3

$$\eta_{he} = \frac{T_3-T_2}{T_5-T_6}\checkmark \qquad \checkmark \quad \checkmark\checkmark$$

$$\therefore T_3 = T_2 + \eta_{he}(T_5 - T_6) = 540{,}923 + 0{,}86(635{,}6 - 575{,}6) = 540{,}923 + 51{,}6$$
$$= 592{,}523\ K\checkmark$$

(3)

4.4

$$Q_{cc} = mCp(T_4 - T_3) = 20 \times 1{,}005(950 - 592{,}523) = 7\,185{,}288\ kJ/s$$

(2)

4.5

$$\eta_t = \frac{Q_t-Q_c}{Q_{cc}} \times 100\% = \frac{6319{,}44-4802{,}353}{7185{,}288\checkmark} \times 100\%$$
$$= 21{,}114\%\checkmark$$

(2)

[20]

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QUESTION 5

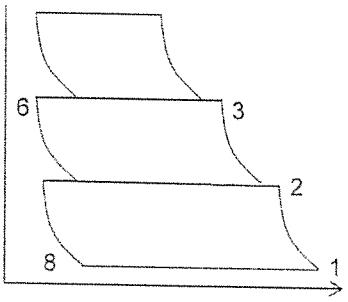
5.1

$$P_c = \frac{xn}{n-1} P_1 Ve_1 \left[\left(\frac{P_x+1}{P_1}\right)^{\frac{n-1}{xn}} - 1\right] \checkmark$$

$$= \frac{3\times1,31}{0,31} \times 105 \times \frac{12,6}{60}\left[\left(\frac{6720}{105}\right)^{\frac{0,31}{3(1,31)}} - 1\right]$$

$$= \frac{3\times1,31}{0,31} \times 105 \checkmark \times 0,21 \checkmark \left[\left(\frac{6720}{105}\right)^{\checkmark\frac{0,31}{3(1,31)}} - 1\right] 7$$

$$= 108,534\ kW \checkmark \quad (6)$$



(3)

5.2

$$r_{ps} = \sqrt[x]{\frac{P_x+1}{P_1}} \checkmark = \sqrt[3]{\frac{6720\checkmark}{105\checkmark}} = 4 \checkmark$$

$$P_1 Ve_1 = mRT_1 \checkmark$$

$$\therefore T_1 = \frac{P_1 Ve_1}{mR} = \frac{105\checkmark\times12,6\checkmark\times60}{15\checkmark\times0,288\times60} = 306,25\ K \checkmark$$

$$T_2' = T_3' = T_4' = T_1\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = T_1(rp_s)^{\frac{n-1}{n}} = 306,25\checkmark(4)^{\checkmark\frac{0,31}{1,31}}$$

$$= 425,156\ K \checkmark$$

$$Q_{int} = mCp(T_2' - T_1) = \frac{15}{60} \times 1,005(425,156 - 306,25)$$

$$= 29,875\ kW \checkmark$$

$$Q_{wj} = \frac{P_c}{x} - Q_{int} \checkmark = \frac{108,534\checkmark}{3\checkmark} - 29,875 \checkmark = 6,303\ kW \checkmark$$

(11)

5.3

$$Ve_1 = \frac{Ve_1}{s} \times \frac{60}{N} = 0,21 \times \frac{60}{240} = 0,052\,5\ m^3/stroke$$

$$Ve_2 = \frac{mRT_2}{P_2} \checkmark = \frac{15\times0,288\times306,25\checkmark}{60\times4\times105\checkmark} = 13,125 \times 10^{-3} m^3/stroke \checkmark$$

$$Ve_3 = \frac{mRT_3}{P_3} \checkmark = \frac{15\times0,288\times306,25\checkmark}{60\times4\times4\times105\checkmark} = 3,281\,25 \times 10^{-3} m^3/stroke \checkmark$$

(6)
[20]

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QUESTION 6

6.1

$At\ 150\ kPa\ and\ 250°C: h_{ss} = 2\ 973\ kJ/kg$
$At\ 160\ kPa: h_g = 2\ 696\ kJ/kg\ \ and\ t_{ss} = 113{,}3°C$

BEFORE $Q_m = m_m[h_{ss} - c_w\Delta t_w]$✓

$\therefore m_m = \frac{Q_m}{h_{ss}-c_w\Delta t_w} = \frac{1577{,}4}{2973-4{,}2(25)} = \frac{1577{,}4}{2868} = 0{,}55\ kg/kg\ fuel$✓

AFTER $h_{ss} = h_g + Cp(t_{ss} - t_s) = 2696 + 2{,}06(160 - 113{,}3) = 2\ 792{,}202\ kJ/kg$

$Q_m = m_m[h_{ss} - c_w\Delta t_w] = 0{,}55[2792{,}202 - 4{,}2(25)] = 1\ 477{,}961\ kJ/kg$ (6)

6.2

BEFORE $Q_g = m_g Cp_g \Delta t_g$✓

$\therefore m_g = \frac{Q_g}{Cp_g\Delta t_g} = \frac{4702{,}5}{1{,}045(250-25)} = 20\ kg$✓

$m_g = m_a + 1 - m_m$✓

$\therefore m_a = m_g - 1 + m_m = 20 - 1 + 0{,}55 = 19{,}55\ kg/kg\ fuel$

AFTER $m_g = m_a - 0{,}5 + 1 - m_m = 19{,}55 - 0{,}5 + 1 - 0{,}55 = 19{,}5\ kg/kg\ fuel$

$Q_g = m_g Cp_g \Delta t_g = 19{,}5 \times 1{,}045(160 - 25) = 2\ 750{,}963\ kJ/kg\ fuel$ (7)

6.3

$At\ 78{,}7°C: h_{fw_1} = 330\ kJ/kg$

BEFORE $\eta_{th} = \frac{m_s[h_{ss}-h_{fw_1}]}{m_f \times CV}$✓ $\times 100\% = \frac{39312[2705-330]}{4200\times28500} \times 100\% = 78\%$✓

AFTER $\eta_{th} = 78 + 2 = 80\%$✓

$\eta_{th} = \frac{m_s[h_{ss}-h_{fw_1}]}{m_f \times CV}$

$\therefore m_s = \frac{\eta_{th} \times m_f \times CV}{h_{ss}-h_{fw_1}} = \frac{0{,}8\times4200\times28500}{2730-330} = 39\ 900\ kg/h$✓ (5)

6.4 AFTER $EE = \frac{m_s[h_{ss}-h_{fw_1}]}{m_f \times 2257} = \frac{39900[2730-330]}{4200\times2257} = 10{,}102$✓ (2)

[20]

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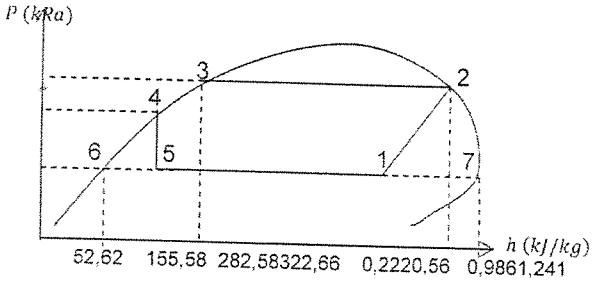
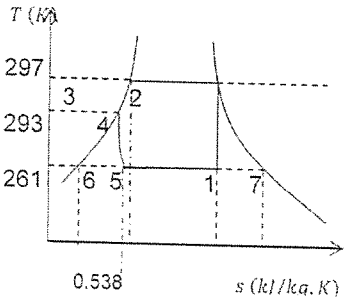
QUESTION 7





7.1

$$s_1 = s_2 = s_6 + x_1(s_7 - s_6)$$

$$x_1 = \frac{s_1 - s_6}{s_7 - s_6} \checkmark = \frac{0,986 \checkmark - 0,222 \checkmark}{1,241 \checkmark - 0,222} = \frac{0.764}{1,019} = 0,75 \checkmark$$

$$h_1 = h_6 + x_1(h_7 - h_6) = 56,62 + 0,75(322,66 - 56,62) = 256,15 kJ/kg$$

$$WD = h_2 - h_1 = 282,58 - 256,16 = 26,43\ kJ/kg$$

(7)

7.2

$$x_5 = \frac{s_5 - s_6}{s_7 - s_6} \checkmark = \frac{0,538 \checkmark - 0,222 \checkmark}{1,241 \checkmark - 0,222} = \frac{0,316}{1,019} = 0,31 \checkmark$$

$$h_5 = h_6 + x_5(h_7 - h_6) = 56,62 + 0,31(322,66 - 56,62) = 139,092\ kJ/kg$$

$$h_s = h_3 - Cp(T_3 - T_4) \checkmark$$

$$Cp = \frac{h_3 - h_5}{T_3 - T_4} = \frac{155,58 - 139,092 \checkmark}{297 - 293 \checkmark} = \frac{16,488}{4} = 4,122\ kJ/kg \checkmark$$

(7)

7.3

$$RE = h_1 - h_5 = 256,15 - 139,092 = 117,092 = 117,058\ kJ/kg$$

$$COP = \frac{RE}{WD} = \frac{117,058 \checkmark}{26,43 \checkmark} = 4,429 \checkmark = 4,429$$

(3)

7.4

$$Q_{econ} = h_2 - h_4 = m_w \times shc \times \Delta t \checkmark$$

$$\therefore m_w = \frac{h_2 - h_4}{shc \times \Delta t} = \frac{282,58 \checkmark - 139,092 \checkmark}{4,2 \checkmark \times 16,6 \checkmark} = \frac{143,488}{69,72} = 2,058\ kg/kg \checkmark$$

(3)
[20]

TOTAL: 100

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