higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

APRIL EXAMINATION

POWER MACHINES N6

31 MARCH 2014

This marking guideline consists of 9 pages.

QUESTION 1

1.1

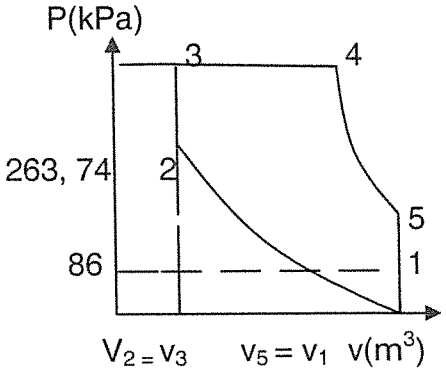
$$V_s = V_1 - V_c = V_1 - 0{,}0625\ V_1$$

$$4\ 500\ cm^3 = 0{,}9375\ V_1$$

$$V_1 = V_5 = \frac{4500}{0{,}9375} = 4\ 800\ cm^3$$

$V_c = V_2 = V_3 = 0{,}0625 \times 4800 = 300\ cm^3$

$$V_4 = \frac{V_5}{9{,}6} = \frac{4800}{9{,}6} = 500\ cm^3$$



(5)

1.2

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^n = 86 \left(\frac{4800}{300}\right)^{1,4} = 86\ (16)^{1,4} = 4171{,}252\ kPa$$

$$T_2 = \left(\frac{V_1}{V_2}\right)^{n-1} = 291\ (16)^{0,4} = 882{,}147\ K$$

$$T_5 = \frac{P_5 . T_1}{P_1} = \frac{263{,}74 \times 291}{86} = 892{,}423\ K$$

$$T_4 = T_5 \left(\frac{V_5}{V_4}\right)^{n-1} = 892{,}423\ (9{,}6)^{0,4} = 2\ 205{,}359\ K$$

$$P_3 = P_4 = P_5 \left(\frac{V_5}{V_4}\right)^n = 263{,}74\ (9{,}6)\ 1{,}4 = 6\ 256{,}85\ kPa$$

$$T_3 = \frac{V_3 . T_4}{V_4} = \frac{300 \times 2205{,}359}{500} = 1\ 323{,}215\ K$$

(9)

1.3

$$Q_{rec} = mCv\ (T_3 - T_2) + mCp\ (T_4 - T_3)$$
$$= 1 \times 0{,}72\ (1\ 323{,}215 - 882{,}147) + 1 \times 1{,}008\ (2\ 205{,}359 - 1\ 323{,}215)$$
$$= 1\ 206{,}77\ kJ/kg$$
$$Q_{rej} = mCv\ (T_1 - T_5) = 1 \times 0{,}72\ (291 - 892{,}423) = -433{,}025\ kJ/kg$$

(4)

1.4

$$\eta_{therm} = \frac{Qrec - Qrej}{Qrec} \times 100\% = \frac{1206{,}77 - 433{,}025}{1206{,}77} \times 100\% = 64{,}117\%$$

(2)
[20]

QUESTION 2

2.1

$$Cp = R + Cv = 0{,}287 + 0{,}718 = 1{,}005\ kJ/kg.K$$

$$\gamma = \frac{Cp}{Cv} = \frac{1{,}005}{0{,}718} = 1{,}4$$

(3)

2.2 $Pc = P_1 \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} = 2\,800 \left(\frac{2}{2,4}\right)^{\frac{1,4}{0,4}}$

$= 1\,479,189$ kPa

$T_c = T_1\left(\frac{2}{\gamma+1}\right) = 723\left(\frac{2}{2,4}\right)$

$= 602,5$ K

$C_c = \sqrt{2\,x103\,Cp(T1-Tc)} = \sqrt{2000\,x\,1,005\,(723-602,5)}$

$= 492,143$ m/s

$V_c = \frac{RTc}{Pc} = \frac{0,287\,x\,602,5}{1479,189} = 0,1169\ m^3/kg$

$A_c = \frac{\pi}{4}\,dc^2 = \frac{\pi}{4}(51)^2 = 2\,042,821\ mm^2$ (8)

2.3 $m = \frac{Ac.Cc}{Vc} = \frac{2042,821\,x\,492,143}{0,1169} \times 10^{-6}$

$= 8,6$ kg /s (2)

2.4 $T_2' = T_1\left(\frac{P2}{P1}\right)^{\frac{\gamma-1}{\gamma}} = 723\left(\frac{590,674}{2800}\right)^{\frac{0,4}{1,4}} = 463,5$ K

$\eta = \frac{Tc - T_2}{Tc - T_2'}$

$T_2 = T_C - \eta(T_C - T_2') = 602,5 - 0,96\,(602,5 - 463,5) = 602,5 - 0,96\,(139)$

$= 469,06$ K

$C_2 = \sqrt{2000\,Cp\,(T1-T2)} = \sqrt{2000\,x\,1,005(723-469,06)}$

$= 714,436$ m/s

$V_2 = \frac{RT2}{P2} = \frac{0,287\,x\,469,06}{590,674} = 0,2279\ m^3/kg$ (7)

[20]

QUESTION 3

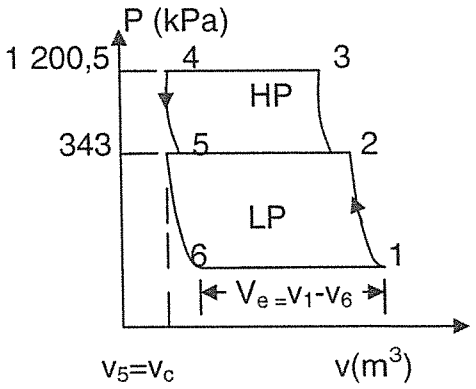
3.1

$$V_s = \frac{\pi}{4} D^2 L = \frac{\pi}{4} (0,245)^2 \times 0,35$$

$$= 0,0165 \text{ m}^2$$

$$V_{e1} = \eta_{vol} \times V_s = 0,9 \times 0,0165$$

$$= 0,01485 \text{ m}^3$$



(4)

3.2 $k = \frac{P3}{P2} = \frac{1200,5}{343} = 3,5$

$P_1 = \frac{P2}{k} = \frac{343}{3,5} = 98 \text{ kPa}$ (2)

3.3 $P_c = \frac{xnP1Ve1}{n-1} [(\frac{P2}{P1})^{\frac{n-1}{n}} - 1] \times \frac{N}{60}$

$= \frac{2 \times 1,3 \times 98 \times 0,01485}{0,3} [(\frac{343}{98})^{\frac{0,3}{1,3}} - 1] \times \frac{355}{60}$

$= 25,016 \text{ kW}$

$P_m = \frac{Pc}{\eta} = \frac{25,016}{0,85} = 29,431 \text{ kW}$ (4)

3.4 $P_1 Ve_1 = mRT_1$

$m = \frac{Pve1}{RT1} \times \frac{N}{60} = \frac{98 \times 0.01485 \times 355}{0,287 \times 303 \times 60}$

$= 0,099 \text{ kg/s}$ (2)

3.5 $T_2 = T_1 \left(\frac{P2}{P1}\right)^{\frac{n-1}{n}} = 303 \left(\frac{343}{98}\right)^{\frac{0,3}{1,3}}$

$= 404,573 \text{ K}$ (2)

3.6 $Q_{int} = mCp (T_2 - T_1) = 0,099 \times 1,005 (404,573 - 303)$

$= 10,106 \text{ kJ/s}$ (2)

3.7 $Q_{wt} = \left(\frac{Pc}{2} - Q\ interc\right) \times 2 = \left(\frac{25,016}{2} - 10,106\right) \times 2$

$= (12,508 - 10,106) \times 2$

$= 4,804 \text{ kJ/s}$ (2)

3.8 $Ve = \frac{m R T2}{p2}$

$= \frac{0,099 \times 60 \times 0,287 \times 404,573}{355 \times 343}$

$= 5,664 \times 10^{-3} m^3$ (2)

[20]

QUESTION 4

4.1 At 24, 1° C : hfw_1 =101 kJ /kg
At 83, 7° C : hfw_2 = 351 kJ /kg

4.1.1

$Q_{econ} = \frac{ms}{mf}(hfw_2 - hfw_1)$

$ms = \frac{Qecon \times mf}{hfw2 - hfw1} = \frac{2200 \times 5750}{351-101} = \frac{2200 \times 5750}{250}$

$= 50\ 600$ kg/h (3)

4.1.2 $\eta = \frac{ms(hss-hfw1)}{mf \times CV}$

$h_{ss} = \frac{\eta \times mf \times CV}{ms} + hfw_1$

$= \frac{0,8012 \times 5750 \times 33000}{50600} + 101$

$= 3\ 004,5 + 101 = 3\ 105,5$ kJ/kg (4)

4.1.3 $Q_{airpreheat} = mCv\Delta t$

$= 20 \times 1,005\ (150 - 25) = 20 \times 1,005\ (125)$

$= 2\ 512,5$ kJ/kg (2)

4.1.4 At 3 500 kPa hf = 1 050 kJ/kg & hfg = 1 752 kJ/kg

$\eta = \frac{ms(hf+xhfg-hfw1)}{mf \times CV} = \frac{50600 \times [1050+0.97\ (1752)-101]}{5750 \times 33000}$

$= \frac{8,8\ (1050+1699,44-101}{33000} = \frac{8,8 \times 2648,44}{33000} \times 100\%$

$= 70,625\%$ (4)

4.2

Q_{in} (kJ/kg)	Q_{out} (kJ/kg)		%
33 000	Q_{econ}	= 2 200	6,667
	Q_{evap} = 8,8 [1 050 + 0,97 (1752) - 351]	= 21 106,27	63,958
	Q_{sup} = 8,8 (3 105,5 - 101) - 2 200 - 21 106,272	= 3 133,328	9,495
	$Q_{Airpreheater}$	= 2 512,5	7,614
	Unaccounted = 33 000 - 28 952,1	= 4 047,902	12,266
33 000		= 33 000	100

(7)
[20]

QUESTION 5

5.1 $BP = \frac{2\pi NT}{60}$

$T = \frac{60BP}{2\pi N} = \frac{60 \times 7,1 \times 10^6}{2\pi \times 240} = 282,5$ kN.m

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

$IP = \frac{BP}{\eta_{mec}} = \frac{7,1 \times 10^6}{0,8} = 8,875$ MW

(4)

5.2 $\eta IT = \frac{IP}{\frac{mf}{s} \times CV}$

$mf/s = \frac{IP}{\eta \times CV} = \frac{8,875 \times 10^3}{0,3901 \times 45500}$

= 0,5 kg/s (2)

5.3 $\eta_{BT} = \frac{BP}{\frac{mf}{s} \times CV} = \frac{7,1 \times 10^3}{0,5 \times 45500}$ OR $= \eta_{IT} \times \eta_{mec}$

= 31,21% = 39, 01 x 0,8
= 31,21% (2)

5.4 $SFC = \frac{mf/h}{IP} = \frac{0,5 \times 60 \times 60}{8,875}$

= 202,817 kg/MW.h (2)

5.5 mg = mf (25 + 1) x 60 = 0,5 (26) x 60
= 780 kg/min (2)

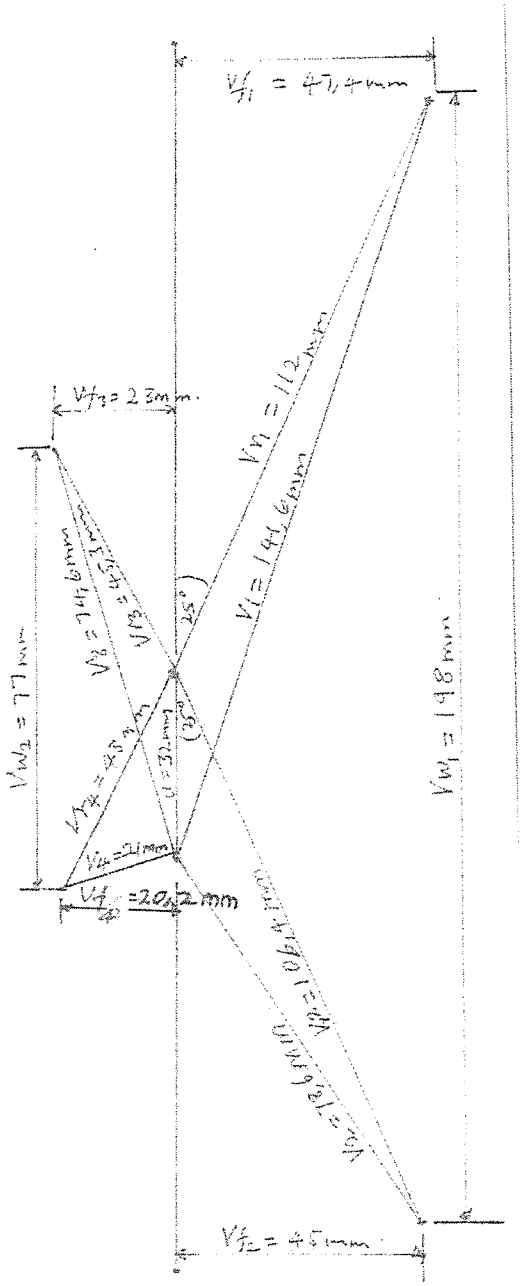
5.6

Q_{in} (MJ /min)	Q_{out} (MJ /min)		%
45,5 x 0,5 x 60 = 1 365	BP = 7,1 x 60	= 426	31,21
	Exhaust = 780 x 10^{-3} x 1,05 (423 -18)	= 331,695	24,3
	Coolant = 1 200 x 10^{-3} x 4,2 x 65	= 327,6	24
	Unaccounted = 1365 - 1093,485	= 279,705	20,49
1 365		= 1 365	100

(8)
[20]

QUESTION 6

6.1



(not to scale) (10)

6.2 $U = \frac{\pi DN}{60} = \frac{\pi \times 1.45 \times 2107,5}{60}$

= 160 m/s

6.2.1 V1 = 141,6 x 5 = 708 m/s

6.2.2 V2 = 78, 6 x 5 = 393 m/s

6.2.3 V_3 = 74, 6 x 5 = 373 m/s

6.2.4 V4 = 21 x 5 = 105 m/s

6.2.5 θ_3 = 30,6 °

6.2.6 β_1 = 35 °

6.2.7 α_2 = 18°

6.2.8 Vr_3 = 45, 3 x 5 = 226,5 m/s

6.2.9 Vr_4 = 43 x 5 = 215 m/s

6.2.10 $\eta = \frac{2U(\Delta Vw\ total)}{V1^2} \times 100\%$

$= \frac{2 \times 160\ (990+385)}{708^2} \times 100\%$

$= \frac{2 \times 160 \times 1375}{708^2} \times 100\%$

= 87, 78 %

(10)
[20]

QUESTION 7

7.1 Ideal C.O.P $= \frac{T1}{T2-T1}$

$= \frac{267}{304-267}$

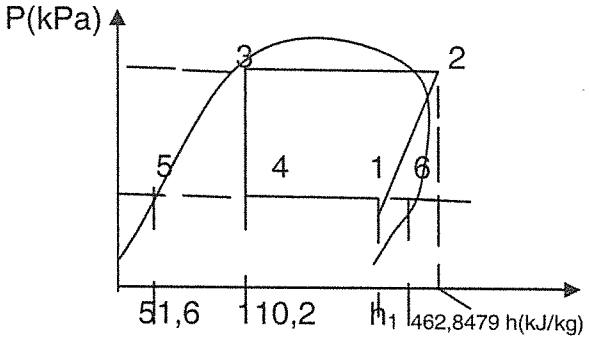
$= \frac{267}{37}$

$= 7,216$

Actual C.O.P $= \eta$ x C.O.P

$= 0,9023 \times 7,216$

$= 6,511$



(3)

7.2 C.O.P $= \frac{h1-h4}{h2-h1}$

C.O.P x $(h_2 - h_1) = h_1 - h_4$

6,511 x $(479 - h_1) = h_1 - 110, 2$

3 118,769 + 110, 2 $= h_1 + 6,511\ h_1$

$h_1 = \frac{3228,969}{7,511}$

$= 429,9$ kJ/kg

$h_1 = h_5 + x_1(h_4 - h_5)$

$x_1 = \frac{h1-h5}{h6-h5} = \frac{429,9 - 51,6}{462,8 - 51,6} = \frac{378,8}{411,2} = 0,92$

(5)

7.3 $V_s = \frac{\pi D^2 L}{4} = \frac{\pi}{4} D^2 \times 1,2\ D$

$= \frac{1,2 \times \pi D^3}{4} = \frac{1,2 \times \pi \times (0,1285)^3}{4}$

$= 0,002\ m^3/s$

$V_s = \frac{0,002 \times 420}{60} = 0,014\ m^3/s$

$Ve = V_s \times \eta_{vol} = 0,014 \times 0,9 = 0,0126\ m^3/s$ (5)

7.4 $V_1 = x_1 - Vg_1 = 0,92 \times 0,168 = 0,155\ m^3/kg$

$m_r = \frac{Ve}{v1} = \frac{0.0126}{0.155} \times 60 = 4,88\ kg/min$ (4)

7.5 $P_c = mr\ (h_2 - h_1) = \frac{4,88}{60}\ (479 - 429,9) = \frac{4,88}{60}\ (49,1)$

$= 4\ kJ/s$

$P_m = \frac{Pc}{\eta_{mech}} = \frac{4}{0,8} = 5\ kW$ (3)

[20]

TOTAL: 100