higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

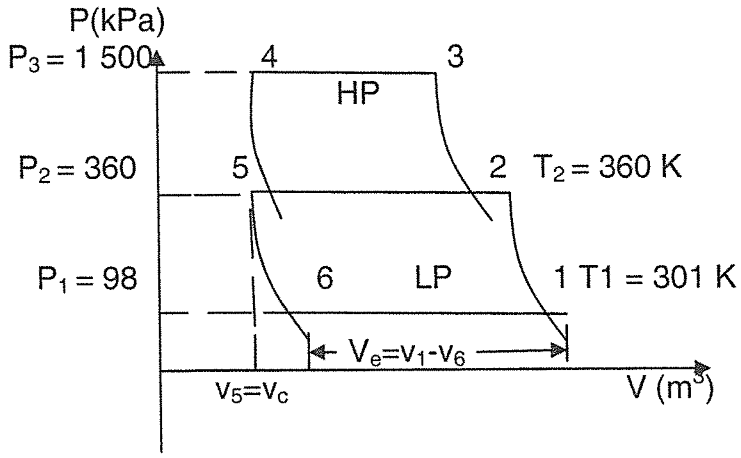
APRIL EXAMINATION

POWER MACHINES N6

2 APRIL 2015

This marking guideline consists of 10 pages.

QUESTION 1



Incomplete intercooling:

1.1

$$P = \frac{nmRT1}{n-1}\left[\left(\frac{P2}{P1}\right)^{\frac{n-1}{n}} - 1\right] + \frac{nmRT2}{n-1}\left[\left(\frac{P3}{P2}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \frac{1{,}3x3x0{,}288x301}{0{,}3x60}\left[\left(\frac{360}{98}\right)^{\frac{0{,}3}{1{,}3}} - 1\right] + \frac{1{,}3x3x0{,}288x360}{0{,}3x60}\left[\left(\frac{1500}{360}\right)^{\frac{0{,}3}{1{,}3}} - 1\right]$$

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

$$P_{req} = \frac{15{,}338}{0{,}85} = 18{,}04 \text{ kW}$$

(7)

1.2

$$V_e = \frac{mRT1}{P1} = \frac{3x0{,}288x301}{2x240x98} = 0{,}005528 \text{ m}^3\text{/stroke}$$

$$Vs_1 = \frac{Ve}{\eta} = \frac{0{,}005528}{0{,}92} = 0{,}006 \text{ m}^3$$

$$Vs_1 = \frac{\pi d^2 L}{4} = \frac{\pi d^2 x1{,}5d}{4}$$

$$0{,}006 = 1{,}17809 \text{ x } d^3$$

d = 0,172 m = 172 mm

(7)

1.3

$$T_2 = T_1\left(\frac{P2}{P1}\right)^{\frac{n-1}{n}} = 301\left(\frac{360}{98}\right)^{\frac{0{,}3}{1{,}3}} = 406{,}4 \text{ K}$$

$$Q_{1\text{-}2} = \frac{mR(T1-T2)}{n-1} + mCv(T_2 - T_1) \quad \& \quad Cv = Cp - R = 1{,}005 - 0{,}288 = 0{,}717 \text{ kJ/kg.K}$$

$$= \frac{3x0{,}288(301-406{,}4)}{2x240x0{,}3} + \frac{3x0{,}717(406{,}4-301)}{2x240}$$

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

(6)
[20]

QUESTION 2

2.1 From steam table: @ 3 000 kPa : hf = 1 008 kJ/kg
hfg = 1 794 kJ/kg
hc = 184kJ /kg he = 741 kJ /kg hs = 2 858 kJ/kg

h_b = hf +xhfg = 1 008 +0,98 x 1 794 = 2 766 kJ/kg

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

Q_b = ms ($h_b - h_e$) = 9.5 (2 766 – 741) = 19 237 kJ

Q_{sh} = ms ($h_s - h_b$) = 9,5 (2 858 – 2 766) = 874 kJ

Q_{ah} = ma.Cp.Δt = 20 x1,005 x (150 – 15) = 2713 kJ (10)

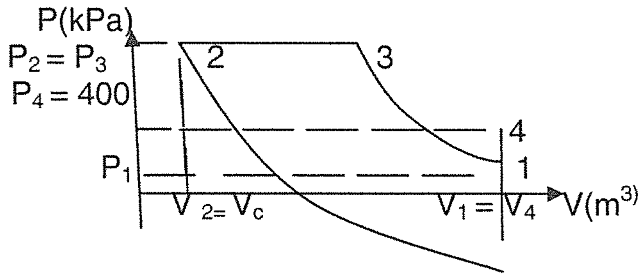
2.2 $\eta = \frac{ms\ (hs - hc)}{mf\ x\ Cv}$

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

= 79,88% (4)

2.3 Heat to flues = heat Supplied -Heat absorbed.
m x Cp x Δt =CV – Ms ($h_s - h_c$) + m_a xCp_axΔt_a
21 x 1,045 (t_{exh} -15) =31 800 -9,5 (2 858 – 184) + 20 x 1,005 x 15
$t_{exh} = \frac{6698{,}5}{21{,}945} + 15$
= 320,24 °C (6)
[20]

QUESTION 3



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

$V_1 = Vs + Vc = 0{,}00636 + 0{,}00041 = 0{,}00677\ m^3$ (4)

3.2 $V_3 = V_2 + \frac{20}{250}.Vs = 0{,}00041 + \frac{20}{250}\ x\ 0{,}00636$

$= 0{,}00092\ m^3$ (3)

3.3 $P_3 = P_4 \left(\frac{V4}{V3}\right)^{ne} = 400 \left(\frac{0{,}00677}{0{,}00092}\right)^{1,28}$

$= 5147{,}13\ kPa$

$P_1 = P_2 \left(\frac{V2}{V1}\right)^{nc} = 5147{,}13 \left(\frac{0{,}00041}{0{,}00677}\right)^{1,35} = 116{,}82\ kPa$ (4)

3.4 $WD/Cycle = P_2 (V_3 - V_2) + \frac{P3\,V3 - P4\,V4}{ne - 1} - \frac{P2\,V2 - P1\,V1}{nc - 1}$

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

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

$\therefore WD/Cycle = 6{,}096\ kJ$ (5)

3.5 $IP = WD/Cycle \times Cycle/second$

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

$= 134{,}11\ kW$ (4)

[20]

QUESTION 4

4.1 $\Delta IP_1 = 56 - 44,2 = 11,8$ kW

$\Delta IP_2 = 56 - 44 = 12$ kW

$\Delta IP_3 = 56 - 43,9 = 12,1$ kW

$\Delta IP_4 = 56 - 44,3 = 11,7$ kW

$\Delta IP_5 = 56 - 44,1 = 11,9$ kW

$\Delta IP_6 = 56 - 43,7 = 12,3$ kW

ΔIP Total = 71,8 kW

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

$$= \frac{56}{71,8} \times 100\% = 77,99\%$$

(7)

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

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

4.3 $m_{exh} /min = m_f /min \times (A/F + 1)$

$= 0,311 \times (15,2 + 1) = 5,038$ kg/min (2)

4.4 $Q_{exh} = m_{exh} \times Cpx \ \Delta T$

$= 5,038 \times 1,1 (400 - 18) = 2116,97$ kJ/min (2)

4.5 $Q_w = m_w . Cp_w . \Delta T = 34 \times 4,187 \times 38 = 5409,6$ kJ/min (2)

4.6

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

(5)
[20]

QUESTION 5

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

$Cc = \sqrt{2000(h1 - hc)}$

$\therefore h_1 - hc = \frac{Cc^2}{2000} = \frac{500^2}{2000} = 125$ kJ/kg

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

hg = 2 768 kJ/kg @ 820 kPa

$h_c = hg + Cp\,(t_{sup} - t_s)$

$\therefore t_{sup} - t_s = \frac{hc - hg}{Cp} = \frac{2800 - 2768}{2{,}56} = 12{,}5$ °C

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

= 171,4 +12, 5 =183,9 °C (6)

5.2 $Vs_{up} = \frac{n-1}{n}\left(\frac{hc - 1941}{Pc}\right) = \frac{0.31}{1.31}\left(\frac{2800 - 1941}{820}\right)$

= 0,2479 m^3/kg

$A_c = \frac{mvc}{Cc} = \frac{5 \times 0{,}2479}{500} = 0{,}002479\ m^2$

= 2479 mm^2

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

$\therefore$ Dc = 56,181 mm (6)

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

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

$V_2 = X_2 \times Vg$

$= 0,95 \times 0,6\,684 = 0,635\ m^3/kg$

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

$C_2 = \frac{mV2}{A2} = \frac{5 \times 0,635}{4094,155 \times 10^{-6}} = 775,5\ m/s$

$C_2 = \sqrt{2000(h1 - h2)}$

$h_1 - h_2 = \frac{(C2)^2}{2000} = \frac{775,5^2}{2000} = 300,7 kJ/kg$

$h_2 = h_1 - 300,7 = 2\,925 - 300,7 = 2\,624,3\ kJ/kg$

(Vg = 0, 6 684, P = 270 kPa)

(hf = 546kJ /kg, hfg = 2 174 kJ/kg @ 270 kPa)

$h_2 = hf + xhfg = 546 + 0,95\,(2\,174)$

$= 2\,611,3\ kJ/kg$

$C_2 = \sqrt{2000(h1 - h2)}$

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

$= 792 m/s$

$A_2 = \frac{m V 2}{C2} = \frac{5 X 0,635}{792}$

$= 4\,008,4 \times 10^{-6}\ m^2$

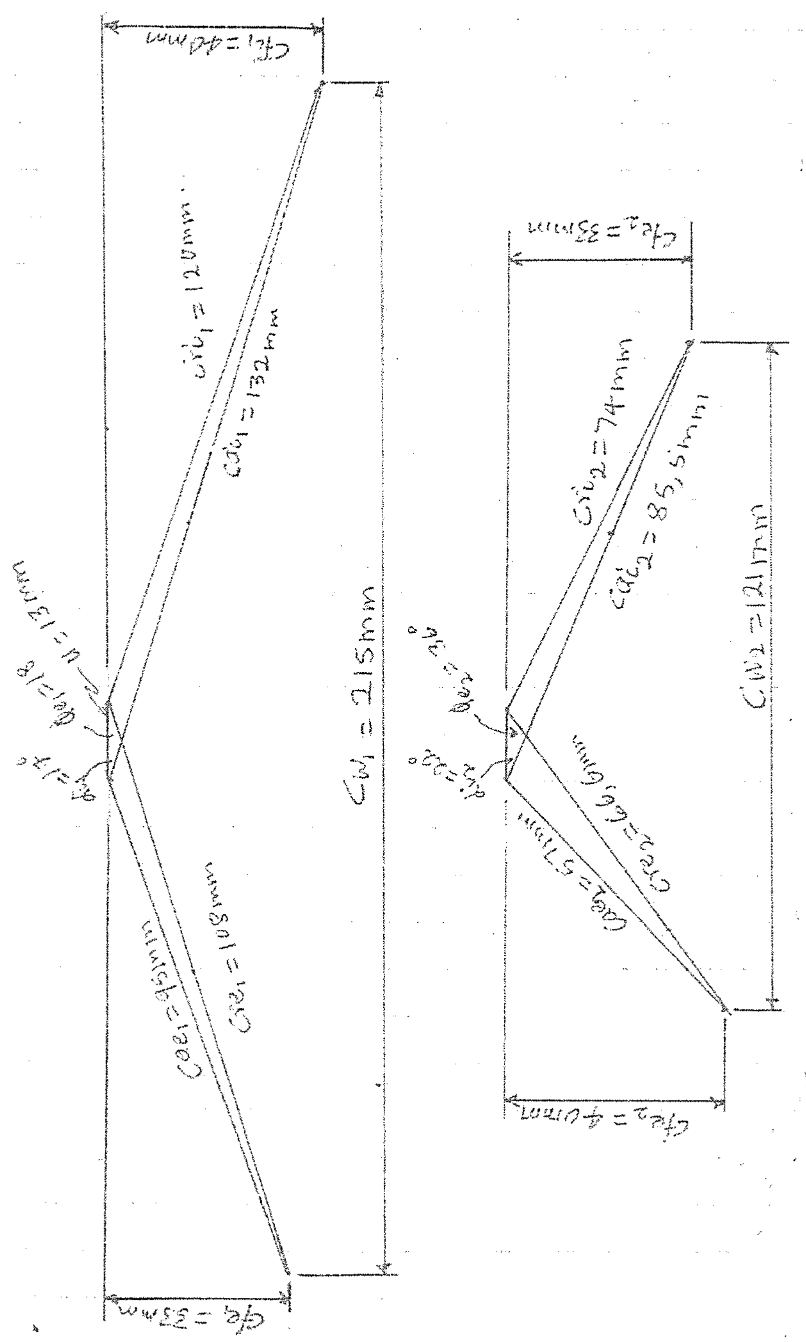
$= 4\,008,4\ mm^2$

(8)

[20]

QUESTION 6

6.1



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

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

$Cai_2 = kCae_1$ = 0, 9 x 95 = 85,5 mm

6.2.1 $F_{Axial} = m(\Delta Cf_i - \Delta Cf_e)$

$= \frac{80(7-7)x5}{60}$

= 0 N

6.2.2 $F_{Tang} = m (\Delta Cw_i - \Delta Cw_e)$

$= \frac{80(215-121)x5}{60}$

= 2 240 N

6.2.3 $P = F_{Tang} x U$

= 2 240 x 64,9

= 145,38 kW

6.2.4 $\eta = \frac{2U(\Delta CWt)}{Cai^2}$

$= \frac{2x64{,}9(1075+605)}{660^2}$

= 50,1%

6.2.5 U = 64,9 m/s

(5 × 2) (10)
[20]

QUESTION 7

7.1 Refrigerating effect $= (q_1 - q_2) \times hfg$

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

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

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

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

$= 6{,}23$ (6)

7.2 Volume at suction $= 0{,}44 \times 5{,}6 \times 0{,}91$
$= 2{,}242\ m^3/min$

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

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

$= 2{,}803\ m^3/min$ (7)

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

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

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

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

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

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

$D = 0{,}31\ m = 310\ mm$ (7)

[20]

TOTAL: 100