higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T1160**(E)**(N18)T

NOVEMBER EXAMINATION

NATIONAL CERTIFICATE

POWER MACHINES N6

(8190046)

18 November 2016 (X-Paper)
09:00–12:00

REQUIREMENTS: **Steam tables (BOE 173)**

Calculators may be used.

This question paper consists of 6 pages and 1 formula sheet of 5 pages.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
POWER MACHINES N6
TIME: 3 HOURS
MARKS: 100

NOTE: If you answer more than the required FIVE questions, only the first five questions will be marked. All work you do not want to be marked must be clearly crossed out.

INSTRUCTIONS AND INFORMATION

1. Answer any FIVE questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Questions may be answered in any order, but subsections of questions must be kept together.
5. ALL formulae used must be written down.
6. Show ALL the intermediate steps.
7. Questions must be answered in blue or black ink.
8. ALL sketches and diagrams must be done in pencil in the answer book.
9. Write neatly and legibly.

QUESTION 1

A three stage compressor is designed for minimum work conditions and delivers air to a pressure of 7 MPa from 103 kPa.

The temperature at the beginning of compression is 30 °C while the index of compression in each stage is 1,3. The clearance volume is ignored and assume Cp as 1,005 kJ/kg, Cv as 0,78 kJ/K.K.

Calculate the following:

1.1	The intermediate pressures in kPa	(6)
1.2	The temperature after compression in the low pressure cylinder	(3)
1.3	The heat extracted per kg air in each intercooler	(3)
1.4	The work done per kg of air delivered	(4)
1.5	The isothermal work done per kg of air and the isothermal efficiency	(4)
		[20]

QUESTION 2

The following information is known about a steam boiler:

The steam pressure is 1,5 MPa
The steam temperature is 350 °C and the SHC of 2,75 kJ/kg. K
The chimney base temperature is 260 °C
The SHC of the dry flue gases is 1,005 kJ/kg. K
The SHC of water is 4,2 kJ/kg. K
The feed water temperature is 54 °C
The boiler room temperature is 29 °C
The chimney base pressure is 100 kPa
The heat value of the fuel is 31 MJ/kg
The heat lost to the steam in the flues is 1,727 MJ/kg coal
The mass of combustibles in the fuel is 0,92 kg/kg fuel
The heat lost to the dry products of combustion per kg coal is 5,321 MJ/kg

Calculate by using steam tables:

2.1	Equivalent evaporation from and at 100 °C	(5)
2.2	The mass of moisture in the flues per kg coal	(7)
2.3	The mass of air per kg coal	(6)
2.4	The percentage hydrogen in the fuel	(2)
		[20]

QUESTION 3

A gas turbine operating according to the Joule cycle has a compressor adiabatic efficiency of 86% and a turbine adiabatic efficiency of 79%. Air is received at 102 kPa and 26 °C while the highest pressure is 830 kPa. The temperature before expansion takes place is 824 °C. The turbine consumes 55 kg of air per second while the heat value of the fuel is 47,4MJ/kg.

Assume R = 0,287 kJ/kg. K, Cp = 1,005 kJ/kg, K and γ = 1,4

Calculate the following:

3.1 All the actual and adiabatic temperatures of the cycle (10)

3.2 The heat gained during combustion in kJ/s (2)

3.3 The mass of fuel consumed in kg/s (2)

3.4 The heat lost during exhaust in kJ/s (2)

3.5 The power developed in kW if the index of compression and expansion is equal to 1,4 (4)

[20]

QUESTION 4

Steam enters a convergent-divergent nozzle at a pressure of 900 kPa and a temperature of 200 °C. The nozzle is designed for maximum delivery and the outlet velocity is 600 m/s. The adiabatic efficiency of the convergent part of the nozzle is 100%, but in the divergent part the loss of enthalpy drop amounts to 10% of the total isentropic enthalpy drop. The inlet area is 400 mm^2 and the mass flow rate is 0,225 kg/s.
The pressure at the throat is 450 kPa and the steam in the throat has a dryness fraction of 0, 98.
The pressure at the outlet is 380 kPa and the steam at the outlet has a dryness fraction of 0,966.

Calculate the following:

4.1 The velocity at the inlet in m/s. (4)

4.2 The area of the throat in mm^2 (6)

4.3 The isentropic enthalpy drop in kJ/kg (6)

4.4 The area at the outlet in mm^2 (4)

[20]

QUESTION 5

A four-cylinder, four stroke petrol engine develops a brake power of 100 kW at an engine speed of 5 500 r/min.
The indicator card shows that the indicator power is 120 kW while the compression ratio is 9 : 1. Each cylinder has a bore size of 95 mm and a stroke length of 90 mm.
The air taken in amounts to 21 kg per kg of fuel consumed. The calorific value of the fuel is 39 MJ/kg and the engine uses 20 kg/h of it.
Assume R = 0,288 kJ/kg. K and γ = 1,41

Calculate the following:

5.1 The indicated mean effective pressure and the mechanical efficiency (5)

5.2 The volumetric efficiency based on air taken in at 101,3 kPa and 15 °C (7)

5.3 The brake thermal efficiency (4)

5.4 The air standard efficiency (2)

5.5 The brake efficiency ratio (2)
[20]

QUESTION 6

The following information refers to a two-stage impulse turbine:

The average blade velocity	= 170 m/s
Friction coefficient across all the blades	= 0,9
The steam mass flow rate	= 2700 kg/min
The steam leaves the nozzle at	= 640 m/s
The inlet angle of the moving blade for the first stage	= 25 °
The inlet angle of the moving blade for the second stage	= 30 °
The scale to be used for construction :	1 cm = 50m/s

The steam leaves the turbine perpendicular to the plane of rotation and the turbine is designed for symmetrical blading for all the stages.

6.1 Construct velocity diagrams for the turbine in the ANSWER BOOK. Indicate the lengths of ALL the lines as well as the magnitude of the angles on the diagrams. (14)

6.2 Determine the following from the velocity diagrams:

6.2.1 The power developed in MW (3)

6.2.2 The axial thrust in N (3)
[20]

QUESTION 7

Methyl chloride, serving as a refrigerating agent in a vapour compressor refrigerator, vaporises between 177 kPa and 967 kPa.
When entering the compressor, the methyl chloride is dry saturated.
After leaving the compressor, the temperature is 102 ºC. The compressor has a cylinder diameter of 80 mm with a stroke length of 75 mm and rotates at 500 r/min. The temperature of the liquid refrigerating agent is 35 ºC at the outlet of the condensator and has a specific heat capacity of 1,62 kJ/kg. K. The volumetric efficiency is 80%.
The specific heat capacity of water is 4,187 kJ/kg. K
The heat transfer of the refrigerating water is 16 592,63 kJ/h.
Assume that the specific heat capacity of the superheated vapour will remain constant.

The following characteristics table refers to the methyl chloride:

Pressure	Saturation temperature	Specific enthalpy (kJ/kg)		Specific entropy (kJ/kg/K)		Specific volume (m^3/kg)	
kPa	(º C)	Liquid (hf)	Vapour (hg)	Liquid (sf)	Vapour (sg)	Liquid V_f	Vapour Vg
177	-10	45,4	460,7	0, 183	1,762	0,00102	0,233
967	45	133	483,6	0, 485	1,587	0,00115	0,046

Calculate the following:

7.1 The specific heat capacity of the superheated vapour (4)

7.2 The coefficient of performance of the refrigerating agent (7)

7.3 The effective swept volume in m^3/h (3)

7.4 The mass of the refrigerating agent in kg/h (3)

7.5 The refrigerating water required by the condenser in kg/h if a temperature rise of 15 ºC is permitted. (3)

[20]

TOTAL: 100

POWER MACHINES N6

FORMULA SHEET

Any applicable formula may also be used.

ENGLISH	***GENERAL***	***AFRIKAANS***
	$P_a V_a = mRT_a$	
	$R = Cp - Cv$	
	$\gamma = \frac{Cp}{Cv}$	
$PV = c$		$PV = k$
$PV^n = c$		$PV^n = k$
$PV^\gamma = c$		$PV^\gamma = k$
	$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$	
	$\Delta U = m \,.\, Cv \,.\, \Delta T$	
$Q = \Delta U + Wd$		$Q = \Delta U + Av$
	$\Delta s = m\left(Cv \,.\, \ln\frac{P_2}{P_1} + Cp \,.\, \ln\frac{V_2}{V_1}\right)$	
	$\Delta s = m \,.\, Cv \,.\, \ln\frac{P_2}{P_1}$	
	$\Delta s = m \,.\, Cp \,.\, \ln\frac{V_2}{V_1}$	
	$\Delta s = m \,.\, R \,.\, \ln\frac{P_1}{P_2}$	
	$Q = m \,.\, Cp \,.\, \Delta T$	
	$Q = m \,.\, Cv \,.\, \Delta T$	
	$S_{su} = S_g + Cp \,.\, \ln\frac{T_{su}}{T_s}$	
	$S_{fg} = S_g - S_f$	
	$S = S_f + xS_{fg}$	
	$h_{su} = h_g + Cp\,(t_{su - t_s})$	

ENGLISH ***GENERAL*** ***AFRIKAANS***

$h_{ws} = h_f + xh_{fg}$

$$V_{su} = \frac{\frac{n-1}{n}(h_{su} - 1941)}{P_{su}}$$

$h_{ns} = h_f + xh_{fg}$

$V_{ws} = xV_g$

$$r = \frac{V_s + V_c}{V_c}$$

$V_{ns} = xV_g$

$$V_s = \frac{\pi}{4} d^2 \times L$$

$$P_2 = \sqrt{P_1 \times P_3}$$

$$r_{ps} = \sqrt[x]{\frac{P_{x+1}}{P_1}}$$

Different formulae for work done (Wd)

Verskillende formules vir arbeid verrig (Av)

$$= P \times \Delta V$$

$$= P_1 V_1 \ln \frac{V_2}{V_1}$$

$$= \frac{P_1 V_1 - P_2 V_2}{n - 1}$$

$$= \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}$$

$$= m \,.\, Cp \,.\, \Delta T$$

$$= \frac{xn}{n-1} P_1 V_e \left[\left(\frac{P_{x+1}}{P_1} \right)^{\frac{n-1}{xn}} - 1 \right]$$

$$= \frac{xn}{n-1} mRT_1 \left[(r_{ps})^{\frac{n-1}{n}} - 1 \right]$$

ENGLISH	***GENERAL***	***AFRIKAANS***

Different formulae for work done (Wd)

= *area of PV-diagram*

= *work done first stage + work done second stage + ...*

$Wd_{nett} = Wd_t - Wd_c$

$Wd_{nett} = Q_{nett}$

Verskillende formules vir arbeid verrig (Av)

= *area van PV-diagram*

= *arbeid verrig eerste stadium + arbeid verrig tweede stadium + ...*

$Av_{nett} = Av_t - Av_k$

$Av_{nett} = Q_{nett}$

Different formulae for air standard efficiencies (ASE)

Verskillende formules vir lugstandaardrendemente (LSR)

$$= 1 - \left(\frac{1}{r}\right)^{\gamma - 1}$$

$$= 1 - \frac{r_p r_c^{\gamma - 1}}{r_v^{\gamma - 1}[(r_p - 1) + \gamma^{r_p}(r_c - 1)]}$$

$$= \frac{heat\ added - heat\ rejected}{heat\ added} = 1 - \frac{\beta^{\gamma} - 1}{r^{\gamma - 1} \times \gamma(\beta - 1)} = \frac{warmte\ toegevoeg - warmte\ afgestaan}{warmte\ toegevoeg}$$

Different volumetric efficiencies, 0_{vol}

$$= \frac{Volume\ of\ air\ taken\ in}{Swept\ volume}$$

$$= \frac{Volume\ of\ free\ air}{Swept\ volume}$$

Verskillende volumetriese rendemente, 0_{vol}

$$= \frac{Volume\ lug\ ingeneem}{Slagvolume}$$

$$= \frac{Volume\ vrylug}{Slagvolume}$$

$$= 1 - \frac{V_c}{V_s}\left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]$$

ENGLISH	***GENERAL***	***AFRIKAANS***
Different thermal efficiencies, $0_{therm.} = \frac{Wd}{heat\ supplied}$		*Verskillende termiese rendemente,* $0_{term.} = \frac{Av}{warmte\ toegevoeg}$
$\eta_{brake\ therm.} = \frac{BP}{m_{f/s} \times CV}$		$\eta_{rem\ term.} = \frac{RD}{m_{b/s} \times WW}$
$\eta_{ind.\ therm.} = \frac{IP}{m_{f/s} \times CV}$		$\eta_{ind.\ term.} = \frac{ID}{m_{b/s} \times WW}$
$\eta_{therm.} = \frac{m_s\ (hs - hw)}{m_f \times CV}$		$\eta_{term.} = \frac{m_s\ (hs - hw)}{m_b \times WW}$
$\eta_c = \frac{T_2' - T_1}{T_2 - T_1}$	$\eta_t = \frac{T_3 - T_4}{T_3 - T_4'}$	$\eta_k = \frac{T_2' - T_1}{T_2 - T_1}$
$\eta_{mech.} = \frac{BP}{IP}$		$\eta_{meg.} = \frac{RD}{ID}$
Indicated efficiency ratio $= \frac{\eta_{ind.\ therm.}}{ASE}$		*Indikateurrendementverhouding* $= \frac{\eta_{ind.\ term.}}{LSR}$
Brake efficiency ratio $= \frac{\eta_{brake\ therm.}}{ASE}$		*Remrendementverhouding* $= \frac{\eta_{rem.\ term.}}{LSR}$
$BP = 2\pi \frac{TN}{60}$	$T = F \times r$	$RD = 2\pi \frac{TN}{60}$
$BP = P_{brake\ mean}\ LANE$		$RD = P_{rem\ gem.}\ LANE$
$IP = P_{ind.\ mean}\ LANE$		$ID = P_{ind.\ gem.}\ LANE$
$ISFC = \frac{m_{f/h}}{IP}$		$ISBV = \frac{m_{b/h}}{ID}$
$BSFC = \frac{m_{f/h}}{BP}$		$RSBV = \frac{m_{b/h}}{RD}$
$COP = \frac{T_1}{T_2 - T_1}$		$KVW = \frac{T_1}{T_2 - T_1}$
$COP = \frac{RE}{Wd}$		$KVW = \frac{VE}{Av}$
$P = m\ .U\ .\Delta Vw$		$D = m\ .U\ .\Delta Vw$
$F_{ax} = m\ .\Delta V_f$		$F_{aks.} = m\ .\Delta V_f$

ENGLISH ***GENERAL*** ***AFRIKAANS***

$$\eta_{dia.} = \frac{2 \, . \, U \, . \, \Delta Vw}{V_1^2}$$

$$P_c = P_1 \left(\frac{2}{\gamma + 1} \right)^{\frac{\gamma}{\gamma - 1}}$$

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

$$C_c = \sqrt{2 \times 10^3 \, (h_1 - h_c) + C_1^2}$$

$$C_2 = \sqrt{2 \times 10^3 \, (h_1 - h_2) + C_1^2}$$

$$C_c = \sqrt{2 \times 10^3 \times C_p \, (T_1 - T_c) + C_1^2}$$

$$C_2 = \sqrt{2 \times 10^3 \times C_p \, (T_1 - T_2) + C_1^2}$$

$$A_c = \frac{mV_c}{C_c} \qquad A_2 = \frac{mV_2}{C_2}$$

$$\eta = \frac{h_1 - h_c}{h_1 - h_c'} \qquad \eta = \frac{T_1 - T_c}{T_1 - T_c'}$$

$$\eta = \frac{h_c - h_2}{h_c - h_2'} \qquad \eta = \frac{T_c - T_2}{T_c - T_2'}$$

$$\eta = \frac{h_1 - h_2}{h_1 - h_2'} \qquad \eta = \frac{T_1 - T_2}{T_1 - T_2'}$$

$$EE = \frac{m_s \, (h_s - h_w)}{m_f \times 2\,257} \qquad EV = \frac{m_s \, (h_s - h_w)}{m_b \times 2\,257}$$

$$\eta_{iso.} = \frac{Wd_{iso.}}{Wd_{poly.}} \qquad \eta_{iso.} = \frac{Av_{iso.}}{Av_{poli.}}$$

$$\eta_{rank.} = \frac{Wd}{Q} \qquad \eta_{rank.} = \frac{Av}{Q}$$