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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

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APRIL EXAMINATION

NATIONAL CERTIFICATE

POWER MACHINES N6

(8190046)

31 March 2014 (Y-Paper)
13:00–16:00

This question paper consists of 7 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 of the seven questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Write neatly and legibly.

QUESTION 1

The volumetric expansion ratio of an engine working on the dual cycle principle is 1 : 9,6.
The clearance volume is 6,25% of the cylinder volume and the swept volume is 4 500 cm³.
At the beginning of the adiabatic compression stroke the conditions indicate a pressure of 86 kPa and a temperature of 18 °C.
The pressure after adiabatic expansion is 263,74 kPa.

Take gamma = 1,4, Cp = 1,008 kJ/kg.K and Cv = 0,72 kJ/kg.K.

Calculate:

1.1 The cylinder volume, clearance volume and the volume before adiabatic expansion in cubic centimetres (5)

1.2 All the missing absolute temperatures and pressures in kPa at the principal points (9)

1.3 The heat received and the heat rejected during the cycle in kJ/kg (4)

1.4 The thermal efficiency of the cycle (2)
[20]

QUESTION 2

Air enters a convergent-divergent nozzle at a pressure of 2 800 kPa, a temperature of 450 °C and a velocity of zero.
The diameter at the throat of the nozzle is 51 mm.
The pressure at the exit is 590,674 kPa.
Up to the throat the flow is frictionless and the efficiency of the divergent part is 96%.

Take R for air = 0,287 kJ/kg.K and Cv = 0,718 kJ/kg.K.

Calculate:

2.1 The value of gamma (3)

2.2 The pressure in kPa, the absolute temperature, the velocity in m/s, the specific volume in m³/kg and the area in mm² at the throat of the nozzle (8)

2.3 The mass flow rate of the air in kg/s (2)

2.4 The absolute isentropic temperature, the absolute actual temperature, the velocity in m/s and the specific volume in m³/kg at the exit of the nozzle (7)
[20]

QUESTION 3

A two-stage, single-acting, reciprocating air compressor delivers air to a receiver at a pressure of 1 200,5 kPa.
The low-pressure cylinder has a piston with a diameter of 245 mm and a stroke length of 350 mm.
The volumetric efficiency of the low-pressure cylinder is 90%.
The temperature at the beginning of the compression stroke for the low-pressure cylinder is 30 °C.
The pressure in the intercooler is 343 kPa.
The compressor rotates at 355 r/min and the mechanical efficiency is 85%.
The index for compression and expansion for both stages is 1,3.
Intercooling is complete for maximum efficiency.

Take R for air as 0,287 kJ/kg.K and Cp as 1,005 kJ/kg.K.

Calculate:

3.1	The swept volume and the effective swept volume for the low-pressure cylinder in cubic metres	(4)
3.2	The pressure before compression in the low-pressure cylinder in kPa	(2)
3.3	The work done in kW for the compressor and the power required to drive the compressor in kW	(4)
3.4	The mass of air delivered by the compressor in kg/s	(2)
3.5	The absolute temperature of the air after compression	(2)
3.6	The heat transfer to the intercooler in kJ/s	(2)
3.7	The heat transfer to the water jackets in kJ/s	(2)
3.8	The effective swept volume of the high-pressure cylinder in cubic metres per cycle	(2)
		[20]

QUESTION 4

A boiler plant burns 5 750 kg of coal with a calorific value of 33 MJ/kg per hour.
It generates superheated steam at a pressure of 3 500 kPa and a temperature of 350 °C.
At the exit from the boiler the steam is 97% dry with a pressure of 3 500 kPa.
The feed-water temperature is 24,1 °C and at entry to the boiler the water has a temperature of 83, 7 °C.
The temperatures at the entrance and the exit of the air preheater are 25 °C and 150 °C respectively.
The thermal efficiency of the plant is 80,12%.
The air fuel ratio is 20 : 1.
The economiser receives 2 200 kJ/kg of heat.
The specific heat capacity of air is 1,005 kJ/kg.K.

4.1 Calculate by using steam tables only:

4.1.1 The mass of superheated steam generated in kg/h (3)

4.1.2 The specific enthalpy of the superheated steam produced at 3 500 kPa in kJ/kg fuel (4)

4.1.3 The heat absorbed by the air preheater in kJ/kg fuel (2)

4.1.4 The thermal efficiency of the plant if the super heater becomes faulty and is disconnected (4)

4.2 Draw up a table of the heat balance in kJ/kg and a percentage for each component to determine the percentage unaccounted for. (7)

[20]

QUESTION 5

A double-acting, two-stroke eight-cylinder diesel engine was tested on a dynamometer at 240 r/min and the following information was obtained:

The brake power	= 7,1 MW
The calorific value of the fuel	= 45,5 MJ/kg
The air-fuel ratio	= 25 : 1
The indicated thermal efficiency	= 39, 01%
The mechanical efficiency	= 80%
The flow rate of the cooling water	= 1 200 kg/min
The temperature rise of the cooling water	= 65 °C
The temperature of the exhaust gases	= 423 °C
The ambient temperature of the air	= 18 °C
The specific heat capacity of the exhaust gases	= 1,05 kJ/kg.K
The specific heat capacity of the cooling water	= 4,2 kJ/kg.K

Calculate:

5.1 The brake torque in kN.m and the indicated power in MW (4)

5.2 The mass of fuel used in kg/s (2)

5.3 The brake thermal efficiency (2)

5.4 The indicated specific fuel consumption in kg/MW.h (2)

5.5 The mass of the exhaust gases in kg/min (2)

5.6 Draw up a table of the heat balance in MJ/min and percentage to determine the percentage heat loss. Assume that the heat to friction is included in the heat consumed by the cooling water. (8)

[20]

QUESTION 6

The average diameter of the moving blades of a two-stage, velocity-compounded, impulse gas turbine, rotating at 2 107,5 r/min is 1,45 m.
The inlet and outlet angles for the first row of moving blades are 25°.
The relative inlet and outlet velocities for the first row of moving blades are 560 m/s and 532 m/s respectively.
The outlet angle for the second row of moving blades is 28°.
The velocity of flow at entry to the second stage is 115 m/s.

6.1 Construct velocity diagrams for the turbine using a scale of 1 mm = 5 m/s. Indicate all the lengths as well as the magnitude of the angles on the diagrams. (10)

6.2 Determine the following from the velocity diagrams:

6.2.1 The nozzle velocity in m/s

6.2.2 The velocity of the gas entering the fixed blades in m/s

6.2.3 The velocity of the gas leaving the fixed blades in m/s

6.2.4 The velocity of the gas leaving the turbine in m/s

6.2.5 The angle at the entrance to the second row of moving blades

6.2.6 The angle at the entrance to the fixed blades

6.2.7 The angle at the exit of the fixed blades

6.2.8 The relative velocity at the entrance of the second row of moving blades in m/s

6.2.9 The relative velocity at the exit of the second row of moving blades in m/s

6.2.10 The diagram efficiency

(10 x 1) (10)
[20]

QUESTION 7

A methyl chloride refrigerating plant operating between pressure limits of 215 kPa and 672 kPa is tested and the following information was obtained:

Temperature of the refrigerant in the condenser	= 31 °C
Temperature of the refrigerant in the evaporator	= -6 °C
Specific enthalpy of dry saturated vapour at condenser pressure	= 479 kJ/kg
Specific enthalpy of dry saturated vapour at evaporator pressure	= 462,8 kJ/kg
Specific enthalpy of saturated liquid at condenser pressure	= 110,2 kJ/kg
Specific enthalpy of saturated liquid at evaporator pressure	= 51,6 kJ/kg
Specific volume of dry saturated vapour at evaporator pressure	= 0,168 m^3/kg

The methyl chloride enters the compressor as a wet vapour. It enters the condenser as a dry saturated vapour and it leaves the condenser as a saturated liquid with no undercooling.
The actual coefficient of performance is 90,23% of the ideal coefficient of performance.
The compressor has a piston with a diameter of 128,5 mm, a stroke length of 1,2 times the diameter of the piston, a volumetric efficiency of 90% and it rotates at 420 r/min.

Calculate:

7.1 The ideal coefficient of performance and the actual coefficient of performance (3)

7.2 The specific enthalpy of the refrigerant at the entrance to the compressor in kJ/kg and the dryness factor (5)

7.3 The swept volume of the compressor in m^3 per stroke, the swept volume and the effective swept volume in m^3/s (5)

7.4 The specific volume of the refrigerant at the entrance to the compressor in m^3/kg and the mass flow rate in kg per minute (4)

7.5 The compressor power in kJ/s and the power required to drive the compressor in kW if the mechanical efficiency is 80% (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***
$h_{ws} = h_f + xh_{fg}$	$V_{su} = \dfrac{\frac{n-1}{n}(h_{su} - 1941)}{P_{su}}$	$h_{ns} = h_f + xh_{fg}$
$V_{ws} = xV_g$	$r = \dfrac{V_s + V_c}{V_c}$	$V_{ns} = xV_g$

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

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

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

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)

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

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

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

Different volumetric efficiencies, 0_{vol}

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

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

Verskillende volumetriese rendemente, 0_{vol}

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

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

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

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

ENGLISH **GENERAL** **AFRIKAANS**

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

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

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

$$C_c = \sqrt{2\times10^3\ (h_1 - h_c) + C_1^2}$$

$$C_2 = \sqrt{2\times10^3\ (h_1 - h_2) + C_1^2}$$

$$C_c = \sqrt{2\times10^3 \times C_p\ (T_1 - T_c) + C_1^2}$$

$$C_2 = \sqrt{2\times10^3 \times C_p\ (T_1 - T_2) + C_1^2}$$

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

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

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

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

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

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

$$\eta_{iso.} = \frac{Wd_{iso.}}{Wd_{poly.}}$$

$$\eta_{iso.} = \frac{Av_{iso.}}{Av_{poli.}}$$

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

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

$$\eta_{carn.} = 1 - \frac{T_2}{T_1}$$

$$h = u + pV$$

$$gZ_1 + U_1 + P_1V_1 + \frac{C_1^2}{2} + Q =$$

$$gZ_2 + U_2 + P_2V_2 + \frac{C_2^2}{2} + Wd$$

$$gZ_1 + U_1 + P_1V_1 + \frac{C_1^2}{2} + Q =$$

$$gZ_2 + U_2 + P_2V_2 + \frac{C_2^2}{2} + Av$$