higher education
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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

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NOVEMBER EXAMINATION

NATIONAL CERTIFICATE

POWER MACHINES N6

(8190046)

18 November 2014 (Y-Paper)
13:00–16:00

This question paper consists of 6 pages and 5 formula sheets.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

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

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. Write neatly and legibly.

Answer any FIVE questions

QUESTION 1

A gas turbine engine working on the constant pressure cycle has a compression adiabatic efficiency of 85%.The ambient air pressure and temperature is 103,4 kPa and 288 K respectively, the actual air temperature after compression is 515 K. 643 kJ of heat is added per kilogram of air per cycle during combustion. Expansion adiabatic efficiency is 82%.
Take gamma as 1,4 and Cp as 1 kJ/kg.K.

Calculate the following:

1.1 The actual and adiabatic temperatures. (9)

1.2 The highest pressure in the cycle (3)

1.3 The compression and expansion indexes (6)

1.4 The heat lost during constant pressure heat rejection per kilogram of air per cycle. (2)

[20]

QUESTION 2

A 4 cylinder, 4 stroke petrol engine was tested on a Prony brake. The brake arm was 1067 mm long and a mass of 15 kg balanced the brake at 2 000 r/min. The mechanical efficiency at this speed was 80% and the brake thermal efficiency was 25%. The air-fuel ratio was 19 to 1. The calorific value of the fuel was 44 200 kJ/kg. The specific heat capacity of the exhaust gas was 1, 05 kJ/kg.K with an exhaust gas temperature rise of 520 °C. The heat to the cooling system was the same as the heat to the exhaust gas per minute. Assume $g = 10\ m/s^2$.

Calculate the following:

2.1 The brake and the indicated power in kW (6)

2.2 The mass of fuel used per minute (4)

2.3 The mass of exhaust gases in kg/min as well as the heat to exhaust gases in kJ/min (4)

2.4 The heat supplied by the fuel per minute and express this as a percentage by tabulating a complete heat balance (6)

[20]

QUESTION 3

A velocity compounded steam turbine has blading designed in such a way that the discharge steam would flow axially from the last row of moving blades. The last stage consisting of two rows of moving blades separated by a fixed blade row has moving blade tip angles of 30° throughout.
The blade speed, the nozzle angle and the fixed blade angles are designed for a nozzle discharge velocity of 500 m/s.
The relative velocity of steam to blades is assumed to reduce by 10% over each row of blading.

3.1 Use a length of 3 cm for the average blade speed to construct velocity diagrams for the turbine. Indicate all the lengths as well as the magnitude of all the angles on the diagrams and calculate the scale from the velocity diagrams. (10)

3.2 Determine from the velocity diagrams:

3.2.1 The blade speed in m/s (1)

3.2.2 The fixed inlet angle of the first stage (1)

3.2.3 The inlet flow velocity of the second stage (1)

3.2.4 The exit relative velocity of the second stage (1)

3.2.5 The power developed per kilogram of steam (3)

3.2.6 The blading efficiency (3)

[20]

QUESTION 4

A three-stage, single acting, reciprocating air compressor has a low pressure cylinder of 450 mm bore and 300 mm stroke. The clearance volume of the low-pressure cylinder is 5% of the swept volume. Intake conditions are 100 kPa and 18 °C. The final delivery pressure is 1 500 kPa. Intermediate pressures are ideal and intercooling is perfect. The compression and expansion index can be taken as 1,3 throughout. Take R = 0,29 kJ/kg.K

Determine the following:

4.1 The intermediate pressures (5)

4.2 The effective swept volume of the low pressure cylinder (5)

4.3 The temperature and volume of air delivered per stroke at 1 500 kPa (5)

4.4 The work done per kg of air (5)

[20]

QUESTION 5

A gas expands in a convergent – divergent nozzle from 500 kPa to 143 kPa.
The initial temperature is 537 °C and the adiabatic efficiency of the nozzle is 92%.
Assume that all losses take place after the throat of the nozzle.
Take gamma = 1, 4 R = 0,288 kJ/kg.K and Cp = 1,008 kJ/kg.K

Calculate the following:

5.1 The pressure and the temperature at the throat of the nozzle (4)

5.2 The specific volume in m³ per kg of gas, the velocity in m/s and the area in mm² per kg of gas at the throat of the nozzle (6)

5.3 The adiabatic and actual temperatures at the exit of the nozzle (4)

5.4 The specific volume in m³ per kg of gas, the velocity in m/s and the area in mm² per kg of gas at the exit of the nozzle (6)

[20]

QUESTION 6

A coal fired boiler plant consists of an economiser, evaporator and superheater. The calorific value of the coal is 32,5 MJ/kg. The evaporator produces steam at 2 500 kPa and there is no pressure drop in the superheater. The plant produces 70 200 kg of steam per hour with a temperature of 300 °C and a specific heat of 2,75 kJ/kg.K. The plant uses 7 800 kg of coal per hour. The feedwater has a temperature of 32,9 °C. The total heat to the economiser is 2 349 kJ/kg and to the evaporator is 21 287 kJ/kg of fuel burned. The pressure and temperature at the chimney base are 100 kPa and 250 °C respectively. The boiler room temperature is 25 °C. The fuel contains 4% of hydrogen by mass. The air-fuel ratio is 18 : 1 and the specific heat capacities of the water is 4, 2 kJ/kg.K and that of the flue gas is 1,045 kJ/kg.K.

Calculate the following:

6.1 The specific enthalpy of the superheated steam and the plant efficiency (5)

6.2 The specific enthalpy of the water entering the evaporator, its temperature from the tables in °C and the dryness factor of the steam leaving the evaporator (4)

6.3 The heat lost to the moisture in the flues in kJ/kg of fuel (3)

6.4 The heat lost to the dry flues in kJ/kg of fuel (3)

6.5 The percentage unaccounted heat lost by tabulating a heat balance in kJ/kg (5)

[20]

QUESTION 7

A vapour compression refrigerator uses ammonia as a cooling agent and operate between temperatures of -12 °C and 30 °C. The ammonia is dry saturated at the end of isentropic compression and saturated liquid at the outlet from the condenser (No undercooling).The following data is supplied:

Heat after compression	=	1 468, 9 kJ/kg
Heat after condensation	=	323, 1 kJ/kg
Liquid heat at evaporator pressure	=	126, 2 kJ/kg
Latent heat at evaporator pressure	=	1 304, 3 kJ/kg
Entropy of dry vapour at condenser pressure	=	4,984 kJ/kg.K
Entropy of liquid at evaporator pressure	=	0, 57 kJ/kg.K
Entropy of dry vapour at evaporator pressure	=	5,504 kJ/kg.K

7.1 Sketch the P–H and T–S diagrams clearly indicating the given values (5)

7.2 Calculate:

7.2.1 The actual coefficient of performance (7)

7.2.2 The power required to produce 1 000 kg of ice at 0 °C in 24 hours from water at 25°C.Take the specific heat capacity of water as 4,187 kJ/kg.K and the latent heat of fusion as 327 kJ/kg. (8)

[20]

TOTAL: 100

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

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

$$V_{ws} = xV_g$$

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

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

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

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

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

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

$$V_{ns} = xV_g$$

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)

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

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

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

Different volumetric efficiencies, η_{vol}

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

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

Verskillende volumetriese rendemente, η_{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, $0_{therm.} = \frac{Wd}{heat\ supplied}$		*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**

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

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

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

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

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

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

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

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

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

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

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

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

$$h = u + pV$$

ENGLISH

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

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

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

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

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

AFRIKAANS

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

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

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

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

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