higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T1400**(E)**(A13)T

NATIONAL CERTIFICATE

POWER MACHINES N6

(8190046)

13 August 2019 (X-Paper)
09:00–12:00

REQUIREMENTS: Properties of Water and Steam (BOE 173)
Superheated Steam Tables (Appendix to BOE 173)
Drawing instruments, pens, a pencil and a ruler

A nonprogrammable calculator may be used.

This question paper consists of 7 pages and a formula sheet of 5 pages.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
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NATIONAL CERTIFICATE
POWER MACHINES N6
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the 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; however, subsections of questions may not be separated.
5. ALL sketches and diagrams must be neat, fully labelled and done in pencil in the ANSWER BOOK.
6. ALL formulae used, must be written out in full.
7. Show ALL intermediate steps for calculations.
8. Use only BLUE or BLACK ink.
9. Final answers must be approximated to THREE decimal places, unless stated otherwise.
10. Write neatly and legibly.

QUESTION 1

The following results were recorded during a test on a two-cylinder, four-stroke, oil engine over a period of one hour:

Fuel consumption	2,3 kg
Rotational frequency	12 r/s
Calorific value of fuel	38 MJ/kg
Brake torque	88 N.m
Mechanical efficiency	78%
Specific heat capacity of water	4,2 kJ/kg/K
Mass of water through exhaust gas calorimeter	212 kg
Temperature of water entering exhaust gas calorimeter	15 °C
Temperature of water exiting exhaust gas calorimeter	63 °C

Use the data provided above to calculate the following quantities:

1.1 The brake power in kW (3)

1.2 The brake thermal efficiency (3)

1.3 The energy carried away by the flue gases in kW (3)

1.4 The energy in kW carried away by the combined effects of the jacket cooling water, friction and radiation (3)

1.5 The percentage heat carried away by the combined effects of the cooling water, friction and radiation (3)

1.6 The indicated power in kW (3)

1.7 The indicated specific fuel consumption in kg/kW.h (2)

[20]

QUESTION 2

A vapour compression refrigeration plant using carbon dioxide as a refrigerant operates between pressure limits of 401 kPa and 997 kPa.

The refrigerant is a wet vapour at the compressor inlet and a dry saturated vapour at the condenser inlet. At the compressor inlet, the refrigerant is 91% dry and at the evaporator inlet, it is 7% dry.

The refrigerant is undercooled to a saturated liquid at 19 °C. Cooling water flows through the condenser at a rate of 861 kg/h from an inlet temperature of 24 °C to an exit temperature of 39 °C.

Assume the specific heat capacity of water is 4,2 kJ/kg.K, the latent heat of fusion of ice is 341 kJ/kg and the refrigerant flow rate is 0,75 kg/min.

The following are extracts from carbon dioxide tables:

Pressure (kPa)	Saturation temperature (°C)	Specific enthalpy (kJ/kg)	
		Liquid (h_f)	Vapour (h_g)
401	-2	172	1 442
997	25	298,9	1 466

Use the data provided above to calculate the following quantities:

2.1 The specific enthalpy of the refrigerant at the compressor inlet (3)

2.2 The specific enthalpy of the refrigerant at the evaporator inlet (3)

2.3 The refrigerating effect in kJ/kg (3)

2.4 The work done by the compressor in kJ/kg (3)

2.5 The actual coefficient of performance (3)

2.6 The energy required to produce ice in kJ/min (2)

2.7 The mass of ice produced at 0 °C, from water at 14 °C, in kg/h (3)
[20]

QUESTION 3

Gas enters the first stage of a velocity compounded, two-stage impulse turbine at an angle of 20° to the blade rotation, with a velocity of 720 m/s.

The average blade velocity is 160 m/s.

The gas enters the second stage at an angle of 18°.

The inlet and outlet angles for the first row of moving blades are equal.

The inlet and outlet angles for the second row of moving blades are equal.

There is a 5% loss of velocity across ALL blades due to friction.

3.1 Use a scale of 1 mm = 5 m/s and construct velocity diagrams for the turbine in the ANSWER BOOK.

Indicate the lengths of ALL lines, as well as the magnitude of ALL angles on the diagrams. (10)

3.2 Determine the following from the diagrams mentioned in QUESTION 3.1:

3.2.1 The outlet angle of the turbine (1)

3.2.2 The velocity of the gas leaving the first stage in m/s (1)

3.2.3 The velocity of the gas entering the second stage in m/s (1)

3.2.4 The velocity of the gas leaving the turbine in m/s (1)

3.2.5 The relative velocity of the gas entering the first row of moving blades in m/s (1)

3.2.6 The relative velocity of the gas leaving the second row of moving blades in m/s (1)

3.2.7 The blading efficiency (4)

[20]

QUESTION 4

During a test on a boiler plant, the following data was recorded:

Boiler pressure	3 MPa
Temperature of the superheated steam	250 °C
Temperature at the chimney base	200 °C
Pressure at the chimney base	200 kPa
Heat carried away by superheated moisture in flue gases	1 235,25 kJ/kg fuel
Mass of superheated moisture in flue gases	0,45 kg/kg fuel
Heat carried away by the dry flue gases	3 311,175 kJ/kg fuel
Calorific value of the fuel	28,56 MJ/kg fuel
Air-fuel ratio	18:1
Feed water temperature	32,9 °C
Specific heat capacity of water	4,2 kJ/kg fuel
Heat absorbed by the economiser	2 352 kJ/kg fuel
Equivalent evaporation from and at 100 °C	10,123

Calculate the following quantities, by making use of steam tables only:

4.1 The atmospheric temperature (3)

4.2 The specific heat capacity of the dry flue gases (4)

4.3 The mass of steam produced per kg of fuel burned (3)

4.4 The thermal efficiency of the plant (3)

4.5 The enthalpy of the feed water entering the evaporator. Thereafter determine the feed-water temperature from the steam tables. (3)

4.6 The heat unaccounted for, in kJ/kg fuel. Also determine the heat unaccounted for as a percentage by drawing a heat-balance-chart. (4)
[20]

QUESTION 5

A gas expands through a convergent-divergent nozzle at a rate of 181 kg/min to an actual temperature of 221 °C.

The nozzle efficiency is 89%, while the throat pressure is 1 581 kPa.

The isentropic temperature drop through the nozzle is 298 °C.

Take gamma for air as 1,4 and R for air as 0,288 kJ/kg.K.

Ignore the velocity of the gas at the inlet and calculate the following quantities:

5.1 At the nozzle inlet:

5.1.1 The absolute temperature of the gas

5.1.2 The pressure of the gas in kPa (2 × 3) (6)

5.2 The value of C_p for the gas (3)

5.3 At the throat of the nozzle:

5.3.1 The absolute temperature of the gas (2)

5.3.2 The velocity of the gas in m/s (2)

5.3.3 The specific volume of the gas (3)

5.4 At the nozzle exit:

5.4.1 The absolute isentropic temperature of the gas

5.4.2 The velocity of the gas in m/s (2 × 2) (4)

[20]

TOTAL: 100

FORMULA SHEET

NOTE: This formula sheet may not necessarily be complete.

Any formula utilised by candidates, which do not appear in this list, must be written in full with the calculations.

ENGLISH	GENERAL	AFRIKAANS
	$P_aV_a = mRT_a$	
	$R = C_p - C_v$	
	$\gamma = \dfrac{C_p}{C_v}$	
$PV = c$		$PV = k$
$PV^n = c$		$PV^n = k$
$PV^\gamma = c$		$PV^\gamma = k$
	$\dfrac{T_2}{T_1} = \left(\dfrac{V_1}{V_2}\right)^{(n-1)} = \left(\dfrac{P_2}{P_1}\right)^{\left(\frac{n-1}{n}\right)}$	
	$\Delta U = m.C_v.\Delta T$	
$Q = \Delta U + Wd$		$Q = \Delta U + Av$

$$\Delta s = m\left[C_v \,.\, \ln\left(\frac{P_2}{P_1}\right) + C_p \,.\, \ln\left(\frac{V_2}{V_1}\right)\right]$$

$$\Delta s = m \,.\, C_v \,.\, \ln\left(\frac{P_2}{P_1}\right)$$

$$\Delta s = m.C_p.\ln\left(\frac{V_2}{V_1}\right)$$

$$\Delta s = m \,.\, R \,.\left(\frac{P_1}{P_2}\right)$$

$$Q = m \,.\, C_p \,.\, \Delta T$$

$$Q = m \,.\, C_v \,.\, \Delta T$$

$$S_{su} = S_g + C_p.\ln\left(\frac{T_{su}}{T_s}\right)$$

$$S_{fg} = S_g - S_f$$

$$S = S_f + x \,.\, S_{fg}$$

$$h_{su} = h_g + C_p \,.\left(t_{su} - t_s\right)$$

$$T_a\left(s_a - s_b\right) = h_a - h_b$$

ENGLISH	GENERAL	AFRIKAANS
$h_{ws} = h_f + x.h_{fg}$	$V_{su} = \dfrac{\frac{n-1}{n}\left(h_{su} - 1\,941\right)}{P_{su}}$	$h_{ns} = h_f + x.h_{fg}$
$V_{ws} = x.V_g$	$r = \dfrac{V_s + V_c}{V_c}$	$V_{ns} = x.V_g$
	$V_s = \dfrac{\pi}{4} \times d^2 \times L$	
	$P_2 = \sqrt{P_1 \times P_3}$	
	$r_{ps} = \sqrt[x]{\dfrac{P_{x+1}}{P_1}}$	

Different formulae for work done (Wd) — verskillende formules vir arbeid verrig (Av)

$$= P \times \Delta V$$

$$= P_1V_1.\ln\left(\frac{V_2}{V_1}\right)$$

$$= \frac{P_1V_1 - P_2V_2}{n-1}$$

$$= \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

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

$$= \frac{xn}{n-1} \times P_1V_e\left[\left(\frac{P_{x+1}}{P_1}\right)^{\left(\frac{n-1}{xn}\right)} - 1\right]$$

$$= \frac{xn}{n-1} \times mRtT_1\left[\left(r_{ps}\right)^{\left(\frac{n-1}{n}\right)} - 1\right]$$

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)

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

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

$$= \frac{heat\ added - heat\ rejected}{heat\ added}$$

$$= 1 - \frac{\beta^{\gamma} - 1}{r^{(\gamma-1)} \times \gamma(\beta - 1)}$$

$$= \frac{warmte\ toegevoeg - warmte\ afgestaan}{warmte\ toegevoeg}$$

Different volumetric efficiencies, η_{vol}

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

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

Verskilllende volumetriese rendemente, η_{vol}

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

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

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

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

ENGLISH GENERAL AFRIKAANS

$$\eta_{dia.} = \frac{2\,.\,U\,.\,\Delta V_w}{(V_1)^2}$$

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

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

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

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

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

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

$$A_c = \frac{m\,.\,V_c}{C_c} \qquad A_2 = \frac{m\,.\,V_2}{C_2}$$

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

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

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

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

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

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

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

$$h = u + pV$$

$$gZ_1+U_1+P_1V_1+\frac{\left(C_1\right)^2}{2}+Q = gZ_2+U_2+P_2V_2+\frac{\left(C_2\right)^2}{2}+Wd$$

$$gZ_1+U_1+P_1V_1+\frac{\left(C_1\right)^2}{2}+Q = gZ_2+U_2+P_2V_2+\frac{\left(C_2\right)^2}{2}+Av$$