higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T1340**(E)**(A8)T

NATIONAL CERTIFICATE

POWER MACINES N6

(8190046)

8 August 2017 (X-Paper)
9:00–12:00

REQUIREMENTS: Steam Tables (BOE 173)

Calculators may be used

This question paper consists of 6 pages and a 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 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

The following data refers to a two-stage, single-acting, reciprocating compressor running at 600 revolution per minute:

The compressor runs under maximum efficiency conditions and the free volume is ignored.
The pressure at the beginning of compression for the low pressure- cylinder is 105 kPa.
Effective swept volume for the low pressure cylinder is 0, 6 m^3/s.
The temperature at the beginning of compression for the low pressure- cylinder is 293K.
The highest pressure for the high pressure cylinder is 900 kPa.
The mechanical efficiency of the compressor is 90 percent.
The specific heat capacity at constant pressure is 1,005 kJ/kg.K and the characteristic gas constant of air is 0,287 kJ/kg.K.
Assume the index for compression is 1,32.

Calculate the following:

1.1 The highest pressure for the low pressure cylinder in kPa. (3)

1.2 The swept volume for the low pressure cylinder in m^3. (3)

1.3 The temperature after compression for the low pressure cylinder in Kelvin. (3)

1.4 The heat absorbed in the intercooler in kJ. (6)

1.5 The work done required to drive the compressor in kJ/s. (5)
[20]

QUESTION 2

In a boiler plant consisting of an evaporator, economiser and superheater, steam is generated at a pressure of 2 MPa and a temperature of 400 °C at a rate of 5 600 kg/h. The temperatures of the feed water entering and leaving the economiser are 47,7 °C and 96,7 °C respectively. The dryness factor of the steam at entry to the superheater is 0,9. Air is supplied at a rate of 15 kg of air per kg of coal. The temperature of the flue gas at the outlet of the economiser is 215°C.The heat value of the coal is 33 000 kJ/kg. The atmospheric temperature is 25 °C.
The specific heat capacity of the flue gases is 1,045 kJ/kg.K and the efficiency of the plant is 84 percent.

Calculate by using steam tables:

2.1 The mass of coal burnt in kg/h (3)

2.2 Equivalent evaporation from and at 100 °C per kilogram of fuel (3)

2.3 Heat to the economiser, evaporator, superheater and chimney in kJ/kg of fuel (9)

2.4 Draw up an energy balance in kJ/kg of fuel and also as a percentage of the total heat. (5)
[20]

QUESTION 3

The following data refers to the Otto-cycle:

The stroke length is the same as the bore size.
The clearance volume is 0,13 times the swept volume.
The rotational speed is 3500 revolution per minute.
The operation is on a four-cylinder, four-stroke principle.
The indicated mean effective pressure is 700 kPa.
The brake power is 85 kW with a mechanical efficiency of 85 percent.
The relative efficiency based on the brake power circumstances is 54 percent.

Calculate the following:

3.1 The bore size and stroke length in mm. (6)

3.2 The stroke volume, free volume and cylinder volume in m^3 (6)

3.3 The volumetric compression ratio to one decimal place (2)

3.4 The air standard efficiency (A.S.E) if gamma is 1,4 (3)

3.5 The brake thermal efficiency (3)
[20]

QUESTION 4

A convergent- divergent nozzle receives superheated steam at a pressure of 800 kPa and a temperature of 250°. Assume the reheat factor is 10% of the overall heat drop due to friction. There is a velocity of 650 m/s, pressure of 400 kPa and the dryness fraction of 0,95 at the exit of the nozzle.
The area at the inlet is 450 mm^2 and the mass flow rate is 0,325 kg/s.
At the throat, there is a pressure of 500 kPa and the dryness fraction of 0, 99.

Calculate the following:

4.1 The inlet velocity of the steam in m/s (4)

4.2 The area at the critical point in mm^2 (6)

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

4.4 The specific volume and the area at the exit in mm^2 (4)
[20]

QUESTION 5

The following information is applicable to a four-stroke, five-cylinder petrol engine, rotating at 6 000 revolution per minute:

Engine brake power	= 150 kW
Engine indicator power	= 200 kW
Bore size	= 96 mm
Stroke length	= 91 mm
Heat value of fuel	= 41 000 kJ/kg
Mass of fuel consumed	= 21 kg/h

Calculate the following:

5.1 The mechanical efficiency and the effective mean brake pressure in kPa. (7)

5.2 The swept volume in m^3/min (3)

5.3 The fuel power and friction power in kW (4)

5.4 The brake thermal efficiency (2)

5.5 The brake torque at 6 000 revolution per minute in N.M (4)
[20]

QUESTION 6

Steam is axially discharged from a velocity compounded, two-stage impulse turbine. The velocity coefficient for all the blades is 5% loss due to friction.
Symmetrical blading occurs in the first and second stage. There is no axial thrust in the second stage. The inlet angle of the moving blade for all the stages is 28°.
The circumferential blade velocity is 160 m/s while the steam leaves the nozzle at a velocity of 700 m/s.

6.1 Construct velocity diagrams for the turbine using 1 cm = 50 m/s scale and 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 inlet flow velocity and the outlet flow velocity for the first stage (2)

6.2.2 The diagram efficiency for the turbine (4)
[20]

QUESTION 7

A vapour-compression refrigerator uses ammonia as a cooling agent, and operates between pressure limits of 500 kPa and 1 300 kPa.
Assume that ammonia is dry saturated at the beginning of compression and is at 60 ºC after compression. The heat transfer required from the condenser unit is 105 MJ/hour.
After the condensating effect, the refrigerating agent is a liquid (not undercooled).
Assume the SHC of the superheated vapour as a constant.

The following characteristics table refers to the ammonia:

Pressure	**Saturation temperature**	**Specific enthalpy (kJ/kg)**		**Specific entropy (kJ/kg/K**	
kPa	(° C)	Liquid (hf)	Vapour (hg)	Liquid (sf)	Vapour (sg)
500	20	52,1	194,3	0,1935	0,6981
1 300	55	85,3	207,3	0,3141	0, 6898

Calculate the following:

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

7.2 The mass of ammonia in kg/s, assume that no loss is observed (7)

7.3 The quality of the steam of ammonia at the entrance to the vaporiser (3)

7.4 The work done in kJ/s of the motor if only 85% of the power is available for ammonia. (6)

[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***
$h_{ws} = h_f + xh_{fg}$	$V_{su} = \dfrac{\frac{n-1}{n}(h_{su} - 1941)}{P_{su}}$	$h_{ns} = h_f + xh_{fg}$
$V_{ws} = xV_g$	$r = \dfrac{V_s + V_c}{V_c}$	$V_{ns} = xV_g$
	$V_s = \dfrac{\pi}{4} d^2 \times L$	
	$P_2 = \sqrt{P_1 \times P_3}$	
	$r_{ps} = \sqrt[x]{\dfrac{P_{x+1}}{P_1}}$	

Different formulae for work done (Wd)

Verskillende formules vir arbeid verrig (Av)

$$= P \times \Delta V$$

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

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

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

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

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

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

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)

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

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

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

Different volumetric efficiencies, η_{vol}

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

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

Verskillende volumetriese rendemente, η_{vol}

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

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

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

ENGLISH	***GENERAL***	***AFRIKAANS***
Different thermal efficiencies, $\eta_{therm.} = \frac{Wd}{heat\ supplied}$		*Verskillende termiese rendemente,* $\eta_{term.} = \frac{Av}{warmte\ toegevoeg}$
$\eta_{brake therm.} = \frac{BP}{m_{f/s} \times CV}$		$\eta_{rem term.} = \frac{RD}{m_{b/s} \times WW}$
$\eta_{ind.\ therm.} = \frac{IP}{m_{f/s} \times CV}$		$\eta_{ind.\ term.} = \frac{ID}{m_{b/s} \times WW}$
$\eta_{therm.} = \frac{m_s\ (hs - hw)}{m_f \times CV}$		$\eta_{term.} = \frac{m_s\ (hs - hw)}{m_b \times WW}$
$\eta_c = \frac{T_2^{'} - T_1}{T_2 - T_1}$	$\eta_t = \frac{T_3 - T_4}{T_3 - T_4^{'}}$	$\eta_k = \frac{T_2^{'} - T_1}{T_2 - T_1}$
$\eta_{mech.} = \frac{BP}{IP}$		$\eta_{meg.} = \frac{RD}{ID}$
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***

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$h = u + pV$$

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

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