higher education
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AUGUST EXAMINATION

NATIONAL CERTIFICATE

POWER MACHINES N6

(8190046)

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This question paper consists of 8 pages and a formula sheet of 6 pages.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
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NATIONAL CERTIFICATE

POWER MACHINES N6

TIME: 3 HOURS

MARKS: 100

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

INSTRUCTIONS AND INFORMATION

1. Answer 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 intake conditions for the low pressure cylinder of a three-stage, double-acting, reciprocating air compressor running at 340 r/min are 103 kPa and 29°C.

The pressure in the second intercooler is 1 632 kPa.

The clearance volume is 4% of the cylinder volume.

The swept volume for the low pressure cylinder is 0,0084 m^3.

The index for compression and expansion is 1,32.

Intercooling is complete and the stage pressures are in geometric progression.

1.1 Calculate:

1.1.1 The stage pressure ratio, the pressure in the first intercooler and the delivery pressure in kPa (3)

1.1.2 The cylinder volume, the clearance volume and the effective swept volume for the low pressure cylinder in m^3 (6)

1.1.3 The power required to drive the compressor in kW (3)

1.1.4 The temperature after compression for each stage (2)

1.1.5 The heat extracted per intercooler in kJ/s if the compressor delivers 336 kg of air per hour and Cp for air is 1,005 kJ/kg.K (2)

1.1.6 The heat transfer to the water jackets per stage in kJ/s (2)

1.1.7 The volumetric efficiency of the low pressure cylinder (2)
[20]

QUESTION 2

The following information was obtained from a test on a steam boiler plant:

The rate of evaporation	=	7 350 kg/h
The pressure in the evaporator and superheater	=	3 000kPa
The temperature of the superheated steam	=	250°C
The temperature of the feed water	=	37,7°C
The temperature of the water at the economiser exit	=	99,6°C
The mass of the coal used	=	750 kg/h
The temperature of the flue gases at entry to the economiser	=	353,33°C
The air supplied per kg fuel burnt	=	18 kg
The specific heat capacity of the flue gases	=	1,045 kJ/kg.K
The thermal efficiency of the plant	=	80 %
The dryness factor of the steam at entrance to the superheater	=	0,975

2.1 Calculate by using steam tables only:

2.1.1 The total heat to the economiser in kJ/kg (2)

2.1.2 The total heat to the evaporator in kJ/kg (2)

2.1.3 The total heat to the superheater in kJ/kg (3)

2.1.4 The calorific value of the coal in kJ/kg (3)

2.1.5 The equivalent evaporation from and at 100°C (2)

2.1.6 The temperature of the flue gases at the chimney base in °C (3)

2.2 Draw up a heat balance in kJ/kg and as a percentage for each component of the plant to determine the heat unaccounted for. (5)

[20]

QUESTION 3

A four-cylinder, four-stroke petrol engine with a piston diameter of 75,15 mm and a stroke length of 90,18 mm was tested while running at 4 800 r/min.

The brake mean effective pressure was 1 250 kPa.

The brake specific fuel consumption was 0,288 kg/kW.h.

The mechanical efficiency was 80%.

The calorific value of the fuel was 39 062,5 kJ/kg.

The clearance volume was 5% of the swept volume.

The value of gamma was 1,41.

3.1 Calculate:

3.1.1 The swept volume of each cylinder in m^3, the brake power in kW and the indicate mean effective pressure in kPa (6)

3.1.2 The brake torque in Nm (2)

3.1.3 The mass of the fuel used in kg/s, the brake thermal efficiency and the indicated thermal efficiency (6)

3.1.4 The volumetric compression ratio, the air standard efficiency and the indicated efficiency ratio (6)

[20]

QUESTION 4

Air flows through a convergent-divergent nozzle at a rate of 150 kg/min to an exit pressure of 237,26 kPa.

At the throat the pressure is 475,454 kPa, the area is 1 534,6 mm^2, the actual temperature is 131,11 °C and the velocity of the air is 398,801 m/s.

The overall efficiency of the nozzle is 92%.

Take gamma for air as 1,4 and Cp as 1,008 kJ/kg.K.

4.1 Ignore the velocity of the air at the inlet and calculate:

4.1.1 The absolute temperature and the pressure in kPa at the inlet (5)

4.1.2 The absolute isentropic temperature, specific volume in m^3/kg at the throat and the percentage heat loss before the throat (6)

4.1.3 The absolute isentropic and actual temperatures, the velocity in m/s and the area mm^2 at the exit. Assume the specific volume to be 0,4154 m^3/kg (8)

4.1.4 The Mach number at the exit (1)

[20]

QUESTION 5

A single-cylinder, single-acting engine working on the diesel cycle rotates at 300 r/min.

It has a piston with a diameter of 187 mm and a stroke length of 233 mm.

Fuel cut-off occurs at 10% of the swept volume after T.D.C.

At the start of compression the pressure is 106 kPa and the temperature is 22,5°C.

The index (n) for compression and expansion is 1,32.

The cylinder volume is 17 times the clearance volume.

R for air is 0,287 kJ/kg.K.

5.1 Calculate:

5.1.1 The swept volume, the clearance volume, the cylinder volume and the volume after combustion in m^3. (5)

5.1.2 The missing absolute temperatures and pressures in kPa at the principal points (8)

5.1.3 The mass of air in kg per cycle and the mass of the air in kg/s (3)

5.1.4 The work done by the engine in kW (4)

[20]

QUESTION 6

A carbon dioxide refrigeration plant operates between limits of -4°C and 28°C.

The refrigerant enters the compressor as a wet vapour and after compression the refrigerant has a temperature of 52,8°C.

In the condenser the refrigerant is undercooled to saturated liquid with a temperature of 23°C.

The refrigerant flows at a rate of 18 kg/min.

The specific heat capacity of the superheated refrigerant is 2,5261 kJ/kg.K and that of the saturated liquid refrigerant is 5,42 kJ/kg.K.

6.1 The following are extracts from carbon dioxide tables:

Saturation temperature	Specific enthalpy (kJ/kg)		Specific entropy (kJ/kg/K	
(° C)	Liquid (hf)	Vapour (hg)	Liquid (sf)	Vapour (sg)
-4	81,4	318,6	0,312	1,183

28	178,6	263,8	0, 638	0,922

Calculate:

6.1.1 The specific entropy in kJ/kg.K after compression and the dryness factor of the refrigerant entering the compressor (5)

6.1.2 The specific enthalpy of the refrigerant at the inlet to the compressor and the specific enthalpy after compressing in kJ/kg (6)

6.1.3 The specific enthalpy of the refrigerant before throttling in kJ/kg, the refrigerating effect in kJ/kg, the work done in kJ/kg, and the actual coefficient of performance (7)

6.1.4 The power required to drive the compressor in kW if the mechanical efficiency is 83%

HINT: Entropy after compression = Entropy of dry saturated vapour at

$$28°C + Cp.\ \ln \frac{T\ after\ compression}{T\ in\ condeser}$$ (2)

[20]

QUESTION 7

A two-stage, velocity-compounded, impulse steam turbine consists of two rows of moving blades separated by a row of fixed blades.

The inlet and outlet angles for the first row of moving blades are 25°C.

The outlet angle for the fixed blades is 16,5°C.

The relative velocity at outlet from the first row of moving blades is 436 m/s.

The outlet angle of the second row of moving blades is 30°C.

The steam is discharged axially from the turbine.

There is a 6% loss of velocity across all the blades due to friction.

7.1 Use the length of 35 mm for the average blade velocity and construct velocity diagrams for the turbine in the answer book and calculate the scale. Indicate the lengths of ALL the lines as well as the magnitude of the angles on the diagrams. (10)

7.2 Determine from the velocity diagrams:

7.2.1 The average blade velocity in m/s

7.2.2 The nozzle velocity in m/s

7.2.3 The velocity of the steam leaving the first stage in m/s

7.2.4 The velocity of the steam entering the second stage in m/s

7.2.5 The velocity of the steam leaving the turbine in m/s

7.2.6 The nozzle angle

7.2.7 The energy developed by the turbine in kJ/kg steam

7.2.8 The blading efficiency

(10)
[20]

TOTAL: 100

FORMULA SHEET

Any applicable formula may also be used.

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

PTO

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 + ...*

Verskillende formules vir arbeid verrig (Av)

= *area van PV-diagram*

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

$$Wd_{nett} = Wd_t - Wd_c \qquad Av_{nett} = Av_t - Av_k$$

$$Wd_{nett} = Q_{nett} \qquad Av_{nett} = Q_{nett}$$

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, 0_{vol}

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$h = u + pV$$

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

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

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

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