higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

POWER MACHINES N6

(8190046)

22 April 2021 (X-paper)
09:00–12:00

REQUIREMENTS: Properties of Water and Steam (BOE 173)
Superheated Steam Tables (appendix to BOE 173)

Nonprogrammable calculators and drawing instruments may be used.

This question paper consists of 6 pages and a formula sheet of 5 pages.

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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 but keep subsections of questions together.
5. All sketches and diagrams must be neat, fully labelled and be drawn in pencil in the ANSWER BOOK.
6. Write down all formulae used.
7. Show all intermediate steps for calculations.
8. Approximate final answers correctly to THREE decimals unless stated otherwise.
9. Use only a black or blue pen.
10. Write neatly and legibly.

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QUESTION 1

A methyl chloride refrigeration plant operates between temperature limits of -8 °C and 26 °C. The refrigerant enters the compressor as a wet vapour and after compression it has a temperature of 55 °C. The condenser undercools the refrigerant to a saturated liquid with a temperature of 22 °C. The specific heat capacity of the superheated refrigerant is 2,6 kJ/kg.K and that of the saturated liquid refrigerant is 5,4 kJ/kg.K.

The following are extracts from methyl chloride tables:

Saturation temperature [°C]	**Specific enthalpy [kJ/kg]**		**Specific entropy [kJ/kg.K]**	
	Liquid (h_f)	Vapour (h_g)	Liquid (s_f)	Vapour (s_g)
-8	74,3	320	0,286	1,2
26	178,4	263,8	0,638	0,922

Calculate:

1.1 The specific entropy of the refrigerant after compression (3)

1.2 The dryness factor of the refrigerant after the evaporator (2)

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

1.4 The specific enthalpy of the refrigerant after compression (3)

1.5 The specific enthalpy of the refrigerant before throttling (2)

1.6 The refrigeration effect in kJ/kg (2)

1.7 The work done in kJ/kg (2)

1.8 The actual coefficient of performance (1)

1.9 The power required to drive the compressor in kW if the mechanical efficiency is 85% and the refrigerant flow rate is 17 kg/min (2)

[20]

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QUESTION 2

A boiler plant burning fuel with a calorific value of 32 MJ/kg generates superheated steam at a pressure of 3,8 MPa and a temperature of 298 °C. At the entrance of the superheater the steam is 98,6% dry. The temperature of the feed water is 29 °C and at the exit from the economiser the feed water has a temperature of 86 °C. The economiser absorbs 2 188 kJ/kg of the heat supplied. The specific heat capacity of the superheated steam is 3,2 kJ/kg.K. The temperatures at the entrance and exit of the air preheater are 26 °C and 137 °C respectively. The air-fuel ratio is 18:1. The temperature of the gas at the chimney base is 177 °C. The specific heat capacity of the air is 1,005 kJ/kg.K. The specific heat capacity of the flue gas is 1,045 kJ/kg.K.

Calculate the following by using steam tables only:

2.1 The mass of steam generated in kg/kg fuel (2)

2.2 The specific enthalpy of the steam generated (3)

2.3 The percentage of the heat supplied absorbed by the evaporator (3)

2.4 The thermal efficiency of the plant (3)

2.5 The percentage of the heat supplied absorbed by the air preheater (3)

2.6 The percentage of the heat supplied carried away by the flue gases (3)

2.7 The thermal efficiency of the plant if the superheater is defective and is removed (3)
[20]

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QUESTION 3

A single-cylinder engine operating on the dual-cycle principle has a cylinder volume of 0,004 8 m^3. Fuel cut-off occurs at 10% of the swept volume after T.D.C. The temperature after compression is 2,75 times that of the initial temperature. The heat received during constant volume combustion is 314,96 kJ/kg gas. The volumetric compression ratio is 18:1. The temperature of the exhaust gas is 1 551 °C. The expansion index (n_e) is 1,32. The pressure after expansion is 6,25 times the initial pressure. Assume C_v for air as 0,72 kJ/kg.°C and C_p as 1,008 kJ/kg.°C.

Calculate:



3.1 The compression index n_c correct to TWO decimals (4)

3.2 The unkn own absolute temperatures and volumes in cm^3 at all principal points (16)

[20]



QUESTION 4

The two rows of moving blades of a velocity-compounded two-stage impulse steam turbine rotate with an average velocity of 105 m/s. The steam is discharged axially with a velocity of 60 m/s. The steam enters the first row of moving blades at an angle of 25° and it enters the second row of moving blades at an angle of 30°. The steam enters the fixed blades at an angle of 36°. There is an 8% loss of velocity across all blades due to friction. The steam flows at 50 kg/s.

4.1 Use a scale of 1 mm = 3 m/s and construct velocity diagrams for the turbine. Indicate the lengths of all lines in mm as well as the magnitude of all angles on the diagrams. (10)

4.2 Determine the following from the diagrams:

4.2.1 The nozzle angle (1)

4.2.2 The axial thrust developed in the turbine in N (3)

4.2.3 The blading efficiency (3)



4.2.4 The power developed in the turbine (3)

[20]

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QUESTION 5

A gas expands in a convergent-divergent nozzle from a pressure of 3 200 kPa to a pressure of 500 kPa. The temperature at the nozzle entrance is 483 °C. The velocity of the gas at the throat is 504 m/s. The temperature drop in the convergent part of the nozzle is 126 °C. The Mach number is 1,54. Assume that all losses occur after the throat.

Ignore the gas velocity at the inlet to the nozzle and calculate:

5.1 The absolute gas temperature at the throat (1)

5.2 The value of gamma for the gas (2)

5.3 The pressure in kPa at the throat (2)

5.4 C_p (2)

5.5 C_v (2)

5.6 R (2)

5.7 The specific volume of the gas at the throat (2)

5.8 At the nozzle exit:

5.8.1 The absolute adiabatic gas temperature (2)

5.8.2 The gas velocity in m/s (1)

5.8.3 The absolute actual gas temperature (2)

5.9 The efficiency of the divergent part of the nozzle (2)

[20]

TOTAL: 100

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FORMULA SHEET

This formulae sheet may not necessarily be complete. Any formula not appearing on this list must be written in full in the ANSWER BOOK.

$$P_a V_a = mRT_a$$

$$R = C_p - C_v$$

$$\gamma = \frac{C_p}{C_v}$$

$$PV = c$$

$$PV^n = c$$

$$PV^\gamma = c$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{(n-1)} = \left(\frac{P_2}{P_1}\right)^{\left(\frac{n-1}{n}\right)}$$

$$\Delta U = m.C_v.\Delta T$$

$$Q = \Delta U + Wd$$

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

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

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

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

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

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

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

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

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

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

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

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

$$V_{ws} = x V_g$$

$$V_{su} = \frac{\frac{n-1}{n}(h_{su} - 1\,941)}{P_{su}}$$

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

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

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

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

Different formulae for work done (Wd)

$$= P \times \Delta V$$

$$= P_1 V_1 . \ln\left(\frac{V_2}{V_1}\right)$$

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

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

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

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

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

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Different formulae for
work done (Wd)

= area of PV - diagram

= work done first stage
+ work done second
stage + ...

$$Wd_{nett} = Wd_t - Wd_c$$
$$Wd_{nett} = Q_{nett}$$

Different formulae for
air standard efficiencies (ASE)

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

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

$$= \frac{heat\ added - heat\ rejected}{heat\ added} \qquad = 1 - \frac{\beta^{\gamma} - 1}{r^{(\gamma-1)} \times \gamma(\beta - 1)} \qquad = \frac{warmt}{}$$

Different volumetric
efficiencies, η_{vol}

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

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

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

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Different thermal efficiencies, $\eta_{therm.}$

$$= \frac{\text{Wd}}{\text{heat supplied}}$$

$$\eta_{brake\ therm.} = \frac{BP}{m_{f/s} \times CV}$$

$$\eta_{ind.\ therm.} = \frac{IP}{m_{f/s} \times CV}$$

$$\eta_{therm.} = \frac{m_s (h_s - h_w)}{m_f \times CV}$$

$$\eta_c = \frac{T_2' - T_1}{T_2 - T_1} \qquad \eta_t = \frac{T_3 - T_4}{T_3 - T_4'}$$

$$\eta_{mech.} = \frac{BP}{IP}$$

Indicated efficiency ratio

$$= \frac{\eta_{ind.\ therm.}}{ASE}$$

Brake efficiency ratio

$$= \frac{\eta_{brake\ therm.}}{ASE}$$

$$BP = 2\pi \frac{TN}{60} \qquad T = F \times r$$

$$BP = P_{brake\ mean}\ L \times A \times N \times E$$

$$IP = P_{ind.\ mean}\ L \times A \times N \times E$$

$$ISFC = \frac{M_{f/h}}{IP}$$

$$BSFC = \frac{M_{f/h}}{BP}$$

$$COP = \frac{T_1}{T_2 - T_1}$$

$$COP = \frac{RE}{Wd}$$

$$P = m\ .\ U\ .\ \Delta Vw$$

$$F_{ex.} = m\ .\ \Delta V_f$$

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

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

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

$$Ma = \frac{C_2}{C_c}$$

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

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

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

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

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

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

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

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

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

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

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

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

$$h = u + pV$$

$$gZ_1 + U_1 + P_1V_1 + \frac{(C_1)^2}{2} + Q = \qquad g.$$

$$gZ_2 + U_2 + P_2V_2 + \frac{(C_2)^2}{2} + Wd \qquad g$$

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