higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NON-NATIONAL CERTIFICATE: ENGINEERING CERTIFICATE OF COMPETENCY

PLANT ENGINEERING: FACTORIES

(8190316)

9 November 2023 (X-paper)
09:00–12:00

CLOSED-BOOK EXAMINATION

Alpha-numerical or programmable calculators may NOT be used.
Non-programmable calculators may be used.

This question paper consists of 7 pages and 1 information sheet.

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PLANT ENGINEERING: FACTORIES

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. Cross out all work that you do not want to be marked.

INSTRUCTIONS AND INFORMATION

1. Answer all the questions in SECTION A.
2. Answer any TWO questions in SECTION B.
3. Read all the questions carefully.
4. Number the answers according to the numbering system used in this question paper.
5. Show all calculations.
6. No marks will be given for calculations in which the steps cannot be clearly followed or for work completed in pencil.
7. Make reasonable assumptions where necessary and clearly state these, together with any formulae used.
8. Rule off across the page on completion of each question.
9. No notes, textbooks, references books or cell phones are allowed in the examination venue.
10. Candidates who were not accepted by the Commission will be disqualified.
11. No candidates may enter the examination room more than 15 minutes after the start of the examination and no candidate may leave the examination room before one hour has elapsed.
12. Write neatly and legibly.

SECTION A (COMPULSORY)

QUESTION 1

1.1 Two kilograms of wet steam at 1,4 MPa from a water supply at 30 °C dissipates 5 200 kJ of heat. The wet steam is then superheated to 215 °C.

Take the specific heat capacity of pure water as 4,187 kJ/kg.K.

STEAM PROPERTIES

P	t_s	v_g	h_f	h_{fg}	h_g	s_f	s_g
kPa	°C	m^3/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg.K	kJ/kg.K
1 400	195	0,140 7	830	1 958	2 788	2,284	6,465

From the chart at 1 400 kPa and 215 °C, h_{sup} = 2 845 kJ/kg.

Given: $V_{sup} = \frac{0{,}231\,(h_{sup} - 1\,941)}{P}$

Calculate:

1.1.1 the initial dryness fraction of the steam

1.1.2 the change in enthalpy

1.1.3 the increase in specific volume

(3 × 4) (12)

1.2 With the aid of a neat, labelled sketch, describe the layout and operation of a water demineralisation plant to supply feedwater to a steam generator from raw water. (8)

[20]

QUESTION 2

2.1 A 10 kVA single-phase transformer, for 2 000 V/400 V at no load, has resistances and leakage reactance as follows.

Primary winding: resistance = 5,5 Ω and reactance = 12 Ω
Secondary winding: resistance 0,2 Ω and reactance = 0,45 Ω

Determine the approximate value of the secondary voltage at full load and 0,8 power factor (lagging), when the primary supply voltage is 2 000 V. (10)

2.2 Draw a typical installation of a pole-mounted transformer to supply 400 V to a rural consumer from a 11 kV spur line. (6)

2.3 Describe and clearly distinguish between touch and step potentials in relation to electrical earth. (4)
[20]

QUESTION 3

3.1 Inputs to the risk assessment processes can include information or data on the following:

- details of location(s) where work is carried out,
- the proximity and scope for hazardous interaction between activities in the workplace,
- security arrangements.

Name FIVE other inputs to this process. (5)

3.2 Name THREE reasons why the plant engineer must be involved with the managing of risks in the working environment. (3)

3.3 Modifications need to be made to a fuel rail tanker that involve welding work at the inlet on top of the tanker. Prepare a hot-work permit for the employees involved with the modifications. (12)
[20]

TOTAL SECTION A: 60

SECTION B

Answer any TWO question in SECTION B.

QUESTION 4

4.1 A power station has three identical 10 MVA, 11 kV three-phase star connected alternators which supply a three-phase busbar system. Connected to these busbars is an 11/66 kV, 10 MVA delta-star transformer. The sequence impedances of each machine are:

	Alternators	Transformer (refer to 11 kV)
Positive (ohm)	j2	j2
Negative (ohm)	j1,8	j2
Zero (ohm)	j0,8	j2

While the star points of two of the alternators are isolated, the star point of the remaining one is solidly earthed. The high voltage winding star point of the transformer is earthed through a 20 ohm effective resistance.

Determine the magnitude of the current which flows to earth from a fault:

4.1.1 on one busbar

4.1.2 on a high voltage terminal of the transformer when the output of the transformer is open circuit when the earth fault occurs.

(15)

4.2 Explain the difference between *open-loop* and *closed-loop control systems* and give an example of each. (5)

[20]

QUESTION 5

5.1 A centrifugal compressor is required to deliver 30 m^3 per hour of free air at 100 kPa and 15 °C. The isentropic efficiency of the machine is 80% and its pressure ratio is 6:1.

Determine the power demand of the compressor. (10)

5.2 Name THREE sensors to be installed on a centrifugal air compressor with four stages and give the reasons for these sensors. (6)

5.3 Centrifugal compressors are mostly used for supplying compressed air. Name FOUR other applications where centrifugal compressors are used. (4)

(20)

QUESTION 6

6.1 A coal-fired power station, A, and a water-powered (hydro) station, B, each have 100 MW capacity. The capital cost per kW of installed capacity of power station A was R100 and that of power station B, R240. The running cost of the station per kWh generated is 0,5 cents for power station A and 0,21 cents for power station B. For each station the annual capital charges are 12%.

If the annual plant load factor of power station A is 42%, calculate the plant load factor of power station B that will make the overall generating cost per kWh the same for both power stations. (10)

6.2 How a power station is earthed or not earthed will determine how that system will react to fault conditions.

Name THREE options when considering the earthing of the neutral point. (4)

6.3 Name TWO types of overhead power line structures that are less vulnerable to vandalism and theft than lattice type structures and name FOUR other advantages of these structures. (6)
[20]

QUESTION 7

7.1 A spherical pressure vessel has an internal diameter of 1 m and a wall thickness of 6 mm. The sphere is filled with water at atmospheric pressure in preparation for a pressure test.

For the material of the sphere $E = 200\ GN/m^2$, $\gamma = 0,3$ and the yield stress, in a tensile test, $\sigma_y = 280\ MN/m^2$.

7.1.1 What extra volume of water must be pumped in to produce a gauge pressure of $3\ MN/m^2$? For water, $K = 2,1\ GN/m^2$. (4)

7.1.2 It is placed in service and pressurised with gas until a volume change of $72 \times 10^{-6}\ m^3$ is reached in the sphere. Determine the pressure exerted by the gas on the wall of the sphere. (4)

7.1.3 At what pressure will failure occur, according to the maximum principal stress theory of failure? (6)

7.2 The data plate on a steam generator has been lost. What procedures shall be followed to replace the data plate to ensure that the steam generator does comply with the regulations? (6)
[20]

QUESTION 8

8.1 A rotating machine with a mass of 180 kg is to be supported on four helical springs to prevent vibration on sensitive equipment in close proximity.

When the machine speed is 900 r/min, there is a primary vertical periodic disturbing force of maximum value 300 N due to the unbalanced reciprocating weights.

Determine the stiffness of each spring to limit the maximum total periodic force on the foundations to 20 N, assuming that the machine vibrates in the vertical direction with no horizontal or angular movement.

What will be the amplitude of vibration of the machine be when its speed is 600 r/min? (10)

8.2 8.2 The electric load at a plant consists of the following:

Lighting: 45 kW
Heating: 80 kW

Five induction motors each supplying 60 kW at a power factor of 0,8 and an efficiency of 93%.

Four induction motors each supplying 120 kW at a power factor of 0,75 and an efficiency of 91%.

One synchronous motor of one MW operating at full load with an efficiency of 92%.

Determine the power factor to which the synchronous motor must be operated to give a plant power factor of unity. (10)
[20]

TOTAL SECTION B: 40
GRAND TOTAL: 100

PLANT ENGINEERING: FACTORIES

INFORMATION SHEET

$P = \sqrt{3}\, VI \cos\theta$	$t = \frac{2A}{C_d\, a\sqrt{2g}} (H_1^{0,5} - H_2^{0,5})$
$Q = C_d\, a_2\, E\sqrt{2g\, H}$	$E = \frac{1}{\sqrt{1 - \left(\frac{a_2}{a_1}\right)^2}}$
$Q = mC\Delta t$	$C = \frac{\sigma_c}{2} bn$
$P = (T_1 - T_2)\, v$	$T = \sigma_s A_s$
$pv = mRT$	$\frac{n}{d-n} = m\frac{\sigma_c}{\sigma_s}$
$\frac{T_1 - T_c}{T_2 - T_c} = e^{\mu\theta}$	$\Delta P = \frac{32\,\mu L v}{D^2}$
$BM_{max} = \frac{WL^2}{8}$	$z = \frac{\pi(D^4 - d^4)}{32.D}$
$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$	$I = \frac{\pi(D^4 - d^4)}{64}$
$x = \sqrt{\frac{P_i}{P_c}}$	$\frac{p_1}{w} + \frac{v_1^2}{2g} = \frac{p_2}{w} + \frac{v_2^2}{2g}$
$\frac{T_2}{T_1} = \left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}$	$a = \left[\frac{P}{m(\omega^2 - p^2)}\right]$ where $\omega^2 = \frac{S}{m}$