higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

POWER MACHINES N5

(8190035)

16 April 2020 (X-paper)
09:00–12:00

REQUIREMENTS: **Steam tables (BOE 173)**
Superheated steam tables (Appendix to BOE 173)

Calculators and drawing instruments may be used.

This question paper consists of 6 pages and a formula sheet of 3 pages.

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NATIONAL CERTIFICATE
POWER MACHINES N5
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. Start each question on a new page.

5.. Write neatly and legibly.

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QUESTION 1

1.1 Complete the sentence by writing only the missing word next to the question number (1.1) in the ANSWER BOOK.

The specific heat capacity at constant pressure is always … than the specific heat capacity at constant volume because at constant pressure the system is allowed to expand. (1)

1.2 Name THREE apparatus used to determine the dryness fraction of steam. (3)

1.3 Various options are given as possible answers to the following questions. Choose the correct answer and write only the letter (A–C) next to the question number (1.3.1–1.3.3) in the ANSWER BOOK.

1.3.1 The vacuum in a condenser is measured with a …

A calorimeter.
B vessel.
C bourdon pressure.

1.3.2 Steam turbines are classified depending on how the steam … takes place.

A diffusion
B condensation
C expansion

1.3.3 The mass on the sleeve of the Hartnell (spring-loaded) governor is replaced by a …

A spring.
B rod.
C load.

(3 × 2) (6)
[10]

QUESTION 2

Polytropic expansion according to $PV^{1.2}$ is encountered by a gas in piston-cylinder from a pressure of 1,5 MPa and an initial volume of 0,25 m^3 to a volume of 0,3 m^3. Take the characteristic gas constant as 0,288 kJ/kg.K and the specific heat capacity at constant volume as 0,717 kJ/kg.K.

Calculate each of the following:

2.1 Pressure after expansion (3)

2.2 Work done (4)

2.3 Ratio of $\frac{T_2}{T_1}$ (2)

2.4 Assume a mass of 1 kg.

Determine each of the following:

2.4.1 T_1 and T_2 (5)

2.4.2 Internal energy (3)

2.4.3 Heat energy (3)

[20]

QUESTION 3

3.1 A plant consists of feed water that is brought in at a temperature of 35 °C. The supply steam is heated until it reaches 350 °C and the pressure of the system is 2500 kPa.

The specific heat capacity of water is 4,187 kJ/kg.K and the specific heat capacity of superheated steam is 2 kJ/kg.K.

Calculate each of the following enthalpies:

3.1.1 Sensible heat in kJ/kg (3)

3.1.2 Latent heat in kJ/kg (2)

3.1.3 Superheat in kJ/kg (3)

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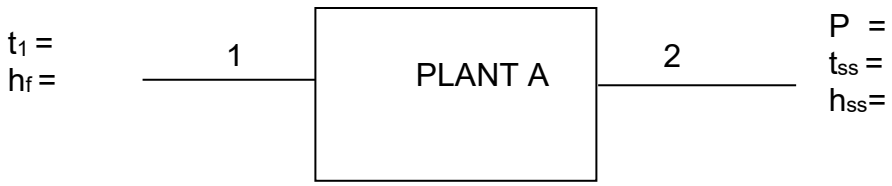
3.2 Feedwater enters the plant at an unknown temperature. 4300 kg steam supplied per hour exits the plant at a pressure of 3000 kPa and a temperature of 350 °C. Coal consumed amounts to 400 kg per hour with a calorific value of 41 000 kJ/kg. The specific heat required to convert water to superheated steam is 3016 kJ/kg.

3.2.1 Show the necessary calculations for t_f and h_f. Redraw the block diagram below in the ANSWER BOOK and complete the missing data for input stream 1 and output stream 2 of the plant (6)



Calculate each of the following:

3.2.2 Plant efficiency (3)

3.2.3 Equivalent evaporation from and at 100 °C (3)

[20]

QUESTION 4

4.1 A single-stage, three-cylinder piston air compressor with a diameter of 180 mm and a stroke length of 2500 mm per cylinder runs at rotational velocity of 240 rpm. The intake pressure is 101,325 kPa and the temperature is 20 °C. Air is delivered at 800 kPa and the index of compression (n) = 1,2. The clearance volume is 5% of the stroke volume. Take the characteristic gas constant as 0,289 kJ/kg.K.

Calculate each of the following:

4.1.1 Stroke volume in m^3 (4)

4.1.2 Mass of air in kg/min (9)

4.1.3 Volumetric efficiency (2)

4.2 A condenser receives 2500 kg of wet steam per hour at 12 kN/m^2. The percentage of dryness factor is 70% and the condensate temperature is 34,6 °C. 340 kilogram per minute of cooling water has an outlet temperature of 12 °C. The specific heat capacity of water is 4,187 kJ/kg.K.

Calculate the inlet temperature of the cooling water. (5)

[20]

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QUESTION 5

A sample of anthracite analysis by mass was determined as follows:

Carbon: 75,1%
Hydrogen: 4,5%
Nitrogen: 1,5%
Oxygen: 5,9%
Sulphur: 5%
Ash: 8%

Atomic mass for C = 12, O = 16, H = 1 and S = 32

5.1 Use the first principle to determine the quantity of air per kg fuel consumed if there is 22% excess air provided to ensure complete combustion. (9)

5.2 Determine the products of combustion and percentage analysis. (6)
[15]

QUESTION 6

The velocity of exiting the nozzle of the impulse stage of a turbine is 800 m/s. The nozzle angle is 20° and a mass flowrate of steam is 2 kg/s. The blades are equiangular. Blade average velocity is 360 m/s. Coefficient of friction is 0,88.

6.1 Construct a velocity diagram in the ANSWER BOOK on landscape to scale 1 cm = 50 m/s. Indicate the velocity values in m/s on the diagram. (10)

6.2 Determine each of the following based on the velocity diagram in QUESTION 6.1:

6.2.1 Blade inlet and outlet angles (2)

6.2.2 Thrust in kN (3)
[15]

TOTAL: 100

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POWER MACHINES N5

FORMULA SHEET

1. $Q = W + \Delta U$
2. $\Delta U = mC_{\upsilon}\Delta T$
3. $Q = mC_{\upsilon}\Delta T$
4. $Q = mC_{p}\Delta T$
5. $Q = P_1V_1 \ln\frac{V_2}{V_1}$
6. $\Delta S = m\left(C_{\upsilon} \ln\frac{T_2}{T_1} + R \ln\frac{V_2}{V_1}\right)$
7. $W = P_1\Delta V$
8. $W = P_1V_1 \ln\frac{V_2}{V_1}$
9. $W = \frac{P_1V_1 - P_2V_2}{n-1}$
10. $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$
11. $R = C_p - C_{\upsilon}$
12. $\gamma = \frac{C_p}{C_{\upsilon}}$
13. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
14. $PV = mRT$
15. $P_1V_1 = P_2V_2$
16. $P_1V_1^n = P_2V_2^n$
17. $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$
18. $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$
19. $h = h_f + \chi h_{fg}$
20. $h = h_g + C_p\Delta T$
21. $h = h_f + h_{fg} = h_g$
22. $V_{\text{sup}} = \frac{n-1}{n}\left(\frac{h_{\text{sup}} - 1\,941}{P}\right)$
23. $\chi = \frac{V_m}{V_g}$
24. $\chi = \frac{M}{M + m}$
25. $U = H - PV$
26. $gZ_1 + U_1 + P_1V_1 + \frac{1}{2}C_1^2 + Q =$

    $gZ_2 + U_2 + P_2V_2 + \frac{1}{2}C_2{}^2 + W$
27. $\eta = \frac{\dot{m}_s(h_2 - h_1)}{\dot{m}_f\, CV}$
28. $EE = \frac{\dot{m}_s(h_2 - h_1)}{\dot{m}_f\ 2\,257}$
29. $p = (B_m \pm M_m)\frac{101{,}325}{760}$

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30. $$m = \frac{100}{23}\left[C\frac{8}{3} + 8H_2 + S - O_2\right]$$

31. $$C_xH_y + \left(x + \frac{y}{4}\right)O_2 = xCO_2 + \frac{y}{2}H_2O$$

32. $$H.C.V. = (CV_C.C) + CV_{H_2}\left(H_2 - \frac{O_2}{8}\right) + (CV_s.S)$$

33. $$L.C.V. = H.C.V. - h_{fg}\ (9H_2)$$

34. $$H.C.V. = \frac{(m_w + m_e)\ C_p\Delta T}{m_f}$$

35. $$W = P_1V_e\left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] = mRT_1\left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

36. $$\eta_c = \frac{V_e}{V_s}.100 = 1 - \frac{Vc}{Vs}\left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right] = 1 + \alpha - \alpha(r_p)^{\frac{1}{n}}$$

37. $$\eta_\alpha = \frac{V_\alpha}{V_s}.100$$

38. $$F_c = \dot{m}(C_{fe} - C_{fi})$$

39. $$P = \dot{m}U[C_{wi} - (-C_{we})]$$

40. $$\eta = \frac{2U[C_{wi} - (-C_{we})]}{C_{ai}{}^2}.100$$

41. $$U = \pi DN$$

42. $$\dot{m}V = AC$$

43. $$(m + M)g = m\omega^2 h$$

44. $$Vs = \frac{\pi}{4}D^2L$$

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45. $\theta_1 = t_c - twi$

46. $\theta_2 = t_c - two$

47. $$Log.temp.diff. = \frac{\theta_1 - \theta_2}{\ell n \frac{\theta_1}{\theta_2}}$$

48. $$Piso = P_1 V_1 \ell n \left(\frac{P_2}{P_1} \right)$$

49. $$Pact = \frac{n}{n-1} P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

50. $$Niso = \frac{Piso}{Pact} \bullet 100$$

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