higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

POWER MACHINES N5

(8190035)

6 December 2023 (X-paper)
09:00–12:00

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

Drawing instruments and nonprogrammable calculators may be used.

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

288Q1G2306

Copyright reserved

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

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. Use only a blue or black pen.
5. Write neatly and legibly.

Copyright reserved

QUESTION 1

1.1 Various options are given as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question number (1.1.1–1.1.2) in the ANSWER BOOK.

1.1.1 What is the final volume if 1 000 m^3 of a gas is compressed to half the original volume?

A 400 m^3
B 700 m^3
C 500 m^3
D 200 m^3

1.1.2 Additional amount of air supplied during combustion

A Actual air
B Theoretical air
C Mass of air
D Excess air

(2 × 1) (2)

1.2 Complete the following sentences by writing only the missing word(s) next to the question number (1.2.1–1.2.3) in the ANSWER BOOK.

1.2.1 The … change the direction of a steam dispensing from the nozzle.

1.2.2 The surface … is cooled by circulating cooling water through it.

1.2.3 The function of a … is to control the speed of an engine.

(3 × 1) (3)
[5]

QUESTION 2

A gas with a volume of 2 m^3 is compressed adiabatically from a temperature of 21 °C and a pressure of 128 kPa until the pressure reaches 270 kPa according to the law $PV^{1,301} = C$. Take the characteristic gas constant as 0,287 kJ/kg.K.

Calculate the following:

2.1 Mass of a gas in kg (3)

2.2 Final volume reached at the end of the adiabatic compression process (4)

2.3 Temperature after adiabatic compression (4)

2.4 Specific heat capacity at constant volume (2)

Copyright reserved

2.5 Internal energy in kJ (3)

2.6 Work done in kJ (4)

[20]

QUESTION 3

Use the steam table to determine the following:

3.1 The specific enthalpy of steam at a pressure of 2050 kPa and a temperature of 285 °C. The specific heat capacity of superheated steam is 2,1 kJ/kg.°C (3)

3.2 The volume in m^3/kg of superheated steam mentioned in QUESTION 3.1. Assume n = 1,3 (3)

3.3 Internal energy in kJ/kg of superheated steam mentioned in QUESTION 3.1 (3)

3.4 The dryness factor for a 2 kg steam at a pressure of 1500 kPa, given the enthalpy of wet steam as 4 800 kilojoules (kJ). (4)

3.5 The volume in m^3 of a wet steam mentioned in QUESTION 3.4 (2)

3.6 Internal energy in kJ of wet steam mentioned in QUESTION 3.4 (3)

3.7 The enthalpy in kJ for 2,5 kg dry steam at a pressure of 880 kPa (2)

[20]

QUESTION 4

4.1 Exhaust steam is condensed in a surface condenser whilst air leaks into the condenser at a rate of 0,08 kg/s. The air pump suction and condensate both have a temperature of 29 °C. The barometer and manometer readings are 740 mmHg and 660 mmHg respectively. The gas constant is 0,289 kJ/kg.K.

Calculate:

4.1.1 Condenser pressure (3)

4.1.2 Air pump capacity in m^3/s (5)

Copyright reserved

4.2 A sample of coal gave the following analysis per 1 kg fuel:

83% carbon
7% hydrogen
3% sulphur
7% oxygen

The latent heat of the moisture formed by combustion is 2453 kJ/kg. Use the following calorific values:
carbon = 34 MJ/kg
hydrogen = 142 MJ/kg
sulphur = 9 MJ/kg

Calculate:

4.2.1 Higher calorific value in MJ/kg (4)

4.2.2 Lower calorific value in MJ/kg (3)
[15]

QUESTION 5

5.1 A single acting reciprocating compressor takes in 15 m^3 of air per minute at 110 kPa and 15 °C and compresses it to a temperature of 400 K according to $PV^{1,2} = C$. The speed is 280 revolutions per minute. Ignore clearance volume. The gas constant is 0,289 kJ/kg.K

Calculate:

5.1.1 Delivery pressure (3)

5.1.2 Work done in kJ (5)

5.2 The arms of a Porter governor are 250 mm in length and the rotating balls each have a mass of 0,8 kg. At the speed of 180 revolutions per minute, the arms form an angle of 30° to the vertical. The central dead load is 2,5 kg. The sleeve movement is $\pm$25 mm.

Calculate sensitivity. (12)
[20]

Copyright reserved

QUESTION 6

6.1 An impulse turbine has a mean blade diameter of 0,84 m and a speed of 4 900 revolutions per minute. A gas with a mass of 3,2 kg leaves the nozzles at an angle of 20°. Blade inlet and outlet angle are both 32°. The coefficient of friction is 0,9.

6.1.1 Calculate the mean blade velocity in m/s. (3)

6.1.2 Draw a velocity diagram in landscape format and indicate all velocity values in m/s. Use a scale of 1 cm = 50 m/s. (10)

6.2 Use the diagram obtained in QUESTION 6.1 to determine the following.

6.2.1 Inlet flow velocity in m/s (2)

6.2.2 Outlet whirl velocity in m/s (2)

6.2.3 Axial thrust (3)

[20]

TOTAL: 100

Copyright reserved

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. $V_{sup} = \frac{n-1}{n}\left(\frac{h_{sup} - 1\,941}{P}\right)$
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. $p = (B_m \pm M_m)\frac{101{,}325}{760}$

Copyright reserved

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

45. $$\theta_1 = t_c - twi$$

Copyright reserved

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

Copyright reserved