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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

# NATIONAL CERTIFICATE

# POWER MACHINES N5

(8190035)

## 29 November 2019 (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 5 pages and a formula sheet of 3 pages.**

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# DEPARTMENT OF HIGHER EDUCATION AND TRAINING
# REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
POWER MACHINES N5
TIME: 3 HOURS
MARKS: 100

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**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. Use only a BLACK or BLUE ink.
6. Write neatly and legibly.

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## QUESTION 1

1.1 The provisions of regulation C91 elaborate on the design, construction and manufacturing of boilers.

State THREE important requirements that must be met before a user is granted permission to use a boiler. (3 × 2) (6)

1.2 Give TWO advantages of a steam-recovery plant. (2 × 2) (4)

**[10]**

## QUESTION 2

0,5 kg gas at 310 kPa is compressed from a volume of 0,15 $m^3$ and a temperature of 40 °C to a pressure of 680 kPa according to the law $pV^{1,35} = C$. The specific heat capacity at constant volume is 0,718 kJ/kg.K.

Calculate:

2.1 The gas characteristic constant in kJ/kg.K (3)

2.2 The final temperature (3)

2.3 The final volume (3)

2.4 The work done during compression (4)

2.5 The change in internal energy (3)

2.6 The heat rejected during compression (4)

**[20]**

## QUESTION 3

A combined separating and throttling calorimeter is used to determine dryness fractions. The barometer reading is 775 mmHg and the manometer reading is 652 mmHg. The mass of condensed steam is 1,5 kg and the mass of water is 0,15 kg. The steam after throttling is at 120 kPa and 110 °C. The specific heat capacity of superheated steam is 2,1 kJ/kg.°C.

Calculate:

3.1 The dryness fraction of the steam in the separating calorimeter (3)

3.2 The dryness fraction of steam in the throttling calorimeter (9)

3.3 The dryness fraction of the steam in the steam mains (4)

3.4 The volume of steam in the mains for 3 kg steam by using the answer to QUESTION 3.3 (4)

**[20]**

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## QUESTION 4

4.1 A condenser receives 8 500 kg steam per hour with a dryness fraction of 0,85. The barometer reading and manometer reading is 760 mmHg and 660 mmHg respectively. The mass of air is 0,25 kg/s whilst air pump and condensate temperature is 45,8 °C. The cooling water enters at 20 °C and leaves at 38 °C. The gas constant is 0,3 kJ/kg.K and the specific heat capacity of water is 4,187 kJ/kg.°C.

Calculate:

4.1.1 The absolute pressure of the steam in the condenser (2)

4.1.2 The mass of cooling water in kg/h (6)

4.1.3 The capacity of the air pump in $m^3$/min (5)

4.2 A watt governor has arms which are 280 mm long. The arms form an angle of 30° with the vertical spindle. The rotating balls each have a mass of 1,2 kg.

Calculate the centrifugal force. (7)

**[20]**

## QUESTION 5

An impulse steam turbine has an average blade peripheral speed of 300 m/s. Steam enters the turbine at 870 m/s with a mass rate of 2 kg/s. The velocity of (axial) flow at the inlet to the turbine is 315 m/s. The angle at which the steam leaves the turbine is 77°. The coefficient of friction is 30%.

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

5.2 Determine each of the following from the velocity diagram drawn in QUESTION 5.1:

5.2.1 The nozzle angle

5.2.2 The outlet flow velocity

(2 × 1) (2)

5.3 Use the diagram drawn in QUESTION 5.1 to determine the diagram efficiency. (3)

**[15]**

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## QUESTION 6

The composite of a sample of fuel according to mass is:

- 85% carbon
- 7% hydrogen
- 6% sulphur
- 2% oxygen

The calorific values are as follows:

- Carbon: 34 MJ/kg
- Hydrogen: 142 MJ/kg
- Sulphur: 9 MJ/kg

The vapour pressure is 5 kPa.

Calculate:

6.1 The higher heat value of the fuel in MJ/kg (3)

6.2 The lower heat value of the fuel in MJ/kg (3)

6.3 If some of the fuel heat is further absorbed by the dry flue (exhaust) gases, calculate the available heat value (AHV) of the fuel in MJ/kg. Air temperature is 36 °C and dry exhaust gas temperature is 230 °C. Take specific heat capacity for exhaust gas as 1,045 kJ/kg.°C. (9)

**[15]**

**TOTAL: 100**

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

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

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46. $\theta_2 = t_c - two$

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

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

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

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

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