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higher education
& training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T1300(E)(A14)T
APRIL EXAMINATION

NATIONAL CERTIFICATE

POWER MACHINES N5

(8190035)

14 April 2015 (Y-Paper)
13:00–16:00

REQUIREMENTS: Steam Tables (BOE 173)
Superheated Steam Tables (Appendix to BOE 173)
Drawing instruments, pens and a ruler

Calculators may be used.

This question paper consists of 5 pages, and a 3-page formula sheet.

DEPARTMENT OF EDUCATION
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. Write the answers to the questions, neatly and legibly, in your answer book.

QUESTION 1

1.1 A bomb calorimeter was used to test the higher heat value (HCV) of a fuel. The information on hand is as follows:

Mass of fuel tested	0,7 g
Mass of water in the calorimeter	2464 g
Water equivalent of the calorimeter	327 g
Temperature of the water before the test	18,5 °C
Temperature of the water after the test	20,69 °C
Specific heat capacity of the water	4,2 kJ/kg.K
The lower heat value of the fuel	13,7% lower than the HCV
Latent heat of the vapour	2453 kJ/kg

Calculate the following:

1.1.1 The higher heat value of the fuel in MJ/kg (4)

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

1.1.3 The percentage of hydrogen content in the fuel (3)

1.2 A sample of coal has the following analysis, according to mass:

Carbon: 86% (Heat value 35 MJ/kg)
Hydrogen: 7% (Heat value 144 MJ/kg
Oxygen: 7%
The partial pressure of the steam in the exhaust gas is 5 kPa.

Calculate the following:

1.2.1 The mass of air required to completely burn 12 kg of coal (4)

1.2.2 The higher heat value of the coal (3)

1.2.3 The lower heat value of the coal (3)

[20]

QUESTION 2

The nozzles of an impulse turbine are inclined at an angle of 22^{o} and the gas exits the nozzles at 540 m/s. The shaft rotates at 6976 r/min and the mean diameter of the wheel is 460 mm. There is no end pressure on the blades of the turbines and there is a 15% loss of velocity due to friction. The mass flow rate of the gas is 1 kg/s.

2.1 Use a scale of 1 cm = 30 m/s and construct a velocity diagram in the answer book. Enter all the values (m/s) onto the diagram.
NB: No marks will be awarded if the values (m/s) are not entered onto the diagram and if the diagram is not constructed to the given scale.
HINT: Use the answer page in the landscape format to construct the diagram. (14)

2.2 From the diagram, determine the following:

2.2.1 The power developed (3)

2.2.2 The kinetic energy that leaves the blades (3)

[20]

QUESTION 3

3.1 18,5 m^3/min of air is supplied to a single-stage, double stroke air compressor at a pressure of 110 kPa and a temperature of 22 °C. The compressor runs at a speed of 400 r/min and delivers the air at a pressure of 820 kPa. Compression takes place according to the law $PV^{1,35} = C$ and the clearance volume is 7% of the stroke volume. The gas constant for air is 0,287 kJ/kg.K.

Calculate the following:

3.1.1 The stroke volume (10)

3.1.2 The temperature of the delivered air (3)

3.1.3 The power required to drive the compressor (3)

3.2 State Dalton's law of partial pressure. (2)

3.3 Steam turbines are classified into two groups. Name the TWO groups. (2)

[20]

QUESTION 4

A volume of gas is compressed polytropically to a pressure of 655 kPa. The gas is compressed according to the law $PV^n = C$, from 0,114 m^3 to ¼ of the original volume. The initial conditions of the gas are 110 kPa and 100 °C. The specific heat capacity at constant volume is 0,754 kJ/kg.K and at constant pressure is 1,05 kJ/kg.K.

Calculate the following:

4.1 The mass of the gas (6)

4.2 The value of the index of compression (7)

4.3 The final, absolute, temperature (3)

4.4 The change of entropy (4)
[20]

QUESTION 5

5.1 3,5 kg of steam is expanded from 2 000 kPa and 300 °C to a pressure of 280 kPa. The specific heat capacity of superheated steam is 2,1 kJ/kg.K. The steam is 10% wet at the latter pressure.

Calculate the total change of internal energy. (17)

5.2 State the THREE phases in which water can exist and give an example of each. (3)
[20]

TOTAL: 100

POWER MACHINES N5

FORMULA SHEET

1. $Q = W + \Delta U$

2. $\Delta U = mC_v \Delta T$

3. $Q = mC_v \Delta T$

4. $Q = mC_p \Delta T$

5. $Q = P_1 V_1 \ln \dfrac{V_2}{V_1}$

6. $\Delta S = m\left(C_v \ln \dfrac{T_2}{T_1} + R \ln \dfrac{V_2}{V_1} \right)$

7. $W = P_1 \Delta V$

8. $W = P_1 V_1 \ln \dfrac{V_2}{V_1}$

9. $W = \dfrac{P_1 V_1 - P_2 V_2}{n - 1}$

10. $W = \dfrac{P_1 V_1 - P_2 V_2}{\gamma - 1}$

11. $R = C_p - C_v$

12. $\gamma = \dfrac{C_p}{C_v}$

13. $\dfrac{P_1 V_1}{T_1} = \dfrac{P_2 V_2}{T_2}$

14. $PV = mRT$

15. $P_1 V_1 = P_2 V_2$

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

18. $\dfrac{T_2}{T_1} = \left(\dfrac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} = \left(\dfrac{V_1}{V_2} \right)^{\gamma-1}$

19. $h = h_f + x h_{fg}$

20. $h = h_g + C_p \Delta T$

21. $h = h_f + h_{fg} = h_g$

22. $V_{sup} = \dfrac{n-1}{n}\left(\dfrac{h_{sup} - 1941}{P} \right)$

23. $x = \dfrac{V_m}{V_g}$

24. $x = \dfrac{M}{M + m}$

25. $U = H - PV$

26. $gZ_1 + U_1 + P_1 V_1 + \dfrac{1}{2} C_1{}^2 + Q =$

$gZ_2 + U_2 + P_2 V_2 + \dfrac{1}{2} C_2{}^2 + W$

27. $\eta = \dfrac{\dot{m}_s (h_2 - h_1)}{\dot{m}_f \, CV}$

28. $EE = \dfrac{\dot{m}_s (h_2 - h_1)}{\dot{m}_f \, 2257}$

29. $p = (B_m \pm M_m) \dfrac{101{,}325}{760}$

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

31. $C_x H_y + \left(x + \dfrac{y}{4} \right) O_2 = xCO_2 + \dfrac{y}{2} H_2 O$

16. $P_1V_1^{\,n} = P_2V_2^{\,n}$

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

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

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

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

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

37. $\eta_a = \dfrac{V_a}{V_s}.100$

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

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

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

41. $KE = \dfrac{1}{2}mv^2$

42. $U = \pi DN$

43. $mV = AC$

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

45. $V_s = \dfrac{\pi}{4}D^2L$

46. $\theta_1 = t_c - twi$

47. $\theta_2 = t_c - two$

48. $$\log.temp.diff. = \frac{\theta_1 - \theta_2}{\ln\frac{\theta_1}{\theta_2}}$$

49. $$P_{iso} = P_1V_1\ln\left(\frac{P_2}{P_1}\right)$$

50. $$P_{act} = \frac{n}{n-1}P_1V_1\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

51. $$\eta_{iso} = \frac{P_{iso}}{P_{act}}.100$$