higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

POWER MACHINES N3

21 April 2021

This marking guideline consists of 5 pages.

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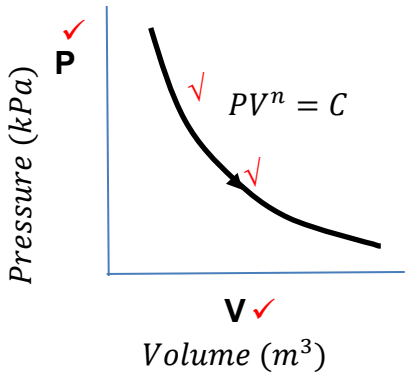
QUESTION 1

1.1



$\frac{1}{2}$ mark for the graph and $\frac{1}{2}$ mark for an arrow in the correct direction
1 mark for each axis (Do not penalise candidates for the units)

(3)

1.2 Heat flows spontaneously from a substance at a higher temperature to a substance at a lower temperature and does not flow spontaneously in the reverse direction (2)

1.3 1.3.1 Speed
1.3.2 The same OR constant OR uniform (2)

1.4 1.4.1 A
1.4.2 C
1.4.3 A

(3×1) (3)
[10]

QUESTION 2

2.1
$\frac{V_1}{V_2} = \frac{3}{1}$
$\frac{4,2}{V_2} = \frac{3}{1}$
$V_2 = 1,4\ m^3$ (3)

2.2
$P_1V_1 = mRT_1$
$m = \frac{120 \times 4,2}{0,288 \times 295}$
$m = 5,932\ kg$ (3)

2.3
$P_1V_1 = P_2V_2$
$P_2 = \frac{120 \times 4,2}{1,4}$
$P_2 = 360\ kPa$

OR

$P_2V_2 = mRT_2$
$P_2 = \frac{5,932 \times 0,288 \times 295}{1,4}$
$P_2 = 359,988\ kPa \approx 360\ kPa$ (3)

2.4
$WD = P_1V_1 ln\frac{V_2}{V_1}$
$WD = (120)(4,2) ln\left(\frac{1}{3}\right)$
$WD = -553,701\ kJ$ (3)

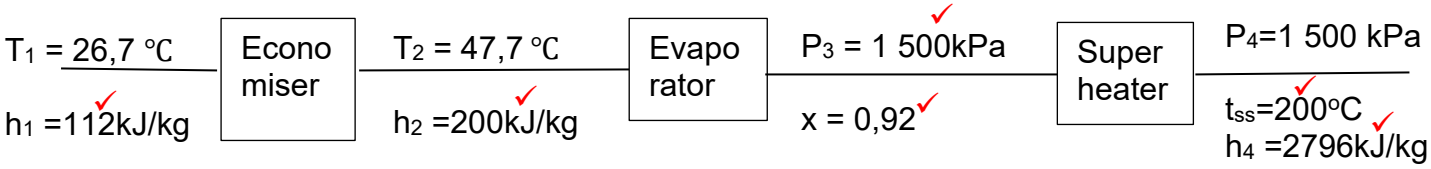
2.5 $\Delta U = mC_v(T_2 - T_1)$
$\Delta U = 5{,}932(0{,}712)(295 - 295)$ ✓
$\Delta U = 0\ kJ$ ✓ (2)

2.6 $\Delta U = 0\ kJ$
$Q = WD$ ✓
$Q = -553{,}701\ kJ$ ✓ (2)

2.7 $\Delta S = m\left[Rln\frac{V_2}{V_1} + C_V ln\frac{T_2}{T_1}\right]$
$\Delta S = 5{,}932\left(0{,}288ln\frac{1}{3} + 0\right)$ ✓ ✓
$\Delta S = 5{,}932kg \times (-0{,}316\frac{kJ}{kg.K})$ ✓ ✓
$\Delta S = -1{,}875\ {}^{kJ}/_{K}$ ✓ (4)
[20]

QUESTION 3

3.1



(6)

3.2 $\frac{m_s}{m_f} = \frac{2500}{200}$
$\frac{m_s}{m_f} = 12{,}5\ \frac{kg\ steam}{kg\ fuel}$ ✓ (1)

3.3 $Heat\ transferred\ to\ the\ economiser = \frac{m_s}{m_f}(h_2 - h_1)$
$= \frac{12{,}5}{1}(200 - 112)$ ✓
$= 1100\ kJ/kg$ ✓ (2)

3.4 $h_3 = h_f + xh_{fg}$ ✓
$h_3 = 845 + (0{,}92)(1845)$ ✓
$h_3 = 2634{,}4\ kJ/kg$ ✓

$Heat\ transferred\ to\ the\ evaporator = \frac{m_s}{m_f}(h_3 - h_2)$
$= \frac{12{,}5}{1}(2634{,}4 - 200)$ ✓
$= 30430\ kJ/kg$ ✓ (5)

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3.5 $Heat\ transferred\ to\ the\ superheater = \frac{m_s}{m_f}(h_4 - h_3)$

$= \frac{12,5}{1}(2796 - 2634,4)$ ✓

$= 2020\ kJ/kg$ ✓ (2)

3.6 $\eta = \frac{m_s}{m_f}(h_4 - h_1)$

$= \frac{12,5}{1}\frac{(2796-112)}{35000} \times 100\ \%$ ✓ ✓

$= 95,857\ \%$ ✓ ✓ (4)

[20]

QUESTION 4

4.1 $Heat\ emitted\ by\ steam = Heat\ absorbed\ by\ water$

$m_s\left[\left(xh_{fg}\right) + c_p(t_{ss} - t_s)\right] = mc_p(T_2 - T_1)$

$100[(0,75 \times 2393) + 4,187(45,8 - 43,8)] = 1850 \times 4,187(T_2 - 22)$ ✓ ✓ ✓ ✓

$100[(1794,75) + 8,375] = 7745,95(T_2 - 22)$

$\frac{180312,4}{7745,95} = (T_2 - 22)$ ✓

$T_2 = 45,278\ ℃$ ✓

Alternative Method

$Heat\ emitted\ by\ steam = Heat\ absorbed\ by\ water$

$m_s\left[\left(h_f + xh_{fg}\right) - (h_c)\right] = mc_p(T_2 - T_1)$

$100[192 + (0,75 \times 2393) - (183)] = 1850 \times 4,187(T_2 - 22)$ ✓ ✓ ✓ ✓

$100[1803,75] = 7745,95(T_2 - 22)$

$\frac{180375}{7745,95} = (T_2 - 22)$ ✓

$T_2 = 45,286\ ℃$ ✓ (6)

4.2 4.2.1 $CH_4 + (1 + \frac{4}{4})O_2 = CO_2 + \frac{4}{2}H_2O$ √

$CH_4 + 2O_2 = CO_2 + 2H_2O$ √

$H_2 + O_2 = H_2O$ √

$H_2 + \frac{1}{2}O_2 = H_2O$ √ OR $2H_2 + O_2 = 2H_2O$ √

$CO + O_2 = CO_2$ √

$CO + \frac{1}{2}O_2 = CO_2$ √ OR $2CO + O_2 = 2CO_2$ √ (3)

4.2.2 $V_{O_2} = (2 \times 0,32) + \left(\frac{1}{2} \times 0,4\right) + (\frac{1}{2} \times 0,2)$ ✓ ✓ ✓

$= 0,94$ ✓ $m^3 oxygen / m^3 fuel$ (4)

4.2.3

$V_{air} = \frac{100}{21} \times 0,94$ √

$V_{air} = 4,476\ {}^{m^3 air}/_{m^3 fuel}$ ✓

$V_{N_2} = \left(\frac{79}{100} \times 4,476\right) + 0,08$ ✓

$V_{N_2} = 3,616\ {}^{m^3 Nitrogen}/_{m^3 fuel}$ √

$V_{CO_2} = 0,32 + 0,2$ √

$V_{CO_2} = 0,52\ {}^{m^3 CO_2}/_{m^3 fuel}$ √

$V_{H_2O} = (2 \times 0,32) + (0,4)$ √

$V_{H_2O} = 1,04\ {}^{m^3 H_2O}/_{m^3 fuel}$ √ (5)

4.2.4

$N_2 = \frac{3,616}{5,176} \times 100 = 69,861\ \%$ √

$H_2O = \frac{1,04}{5,176} \times 100 = 20,093\ \%$ √

$CO_2 = \frac{0,52}{5,176} \times 100 = 10,046\%$ √

$Total = 100\ \%$ √ (2)

[20]

QUESTION 5

5.1

$S_v = V_1 - V_C$ .....(1)

$V_c = 0,03S_V$ ✓.....(2) *Substitute (2) into (1)*

$S_v = V_1 - 0,03S_v$ ✓

$\therefore V_1 = 1,03S_v$ ✓.....(3)

$V_4 = V_3 \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$.....(4) *Substitute (2) into (4)*

$V_4 = 0,03S_V \left(\frac{780}{102}\right)^{\frac{1}{1,35}}$ ✓

$\therefore V_4 = 0,135S_V$ ✓.....(5)

$V_e = V_1 - V_4$ .....(6) *Substitute (3)and (5) into (6)*

$2 = 1,03S_V - 0,135S_V$

$2 = 0,895S_V$ ✓

$S_V = 2,235\ \frac{m^3}{min}$ ✓$\times \frac{min}{300\ rev}$ ✓

$\therefore S_V = 0,00745\ m^3$ ✓ (9)

Alternative method

$V_c = 0{,}03S_V$

$\eta_{vol} = \left[1 - \frac{V_c}{S_V}\left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]\right] \times 100\%$ ✓

$\eta_{vol} = \left[1 - \frac{0{,}03S_V}{S_V}\left[\left(\frac{780}{102}\right)^{\frac{1}{1{,}35}} - 1\right]\right] \times 100\%$

$\eta_{vol} = 89{,}462\%$ ✓

$\eta_{vol} = \frac{V_e}{S_V} \times 100\%$ ✓

$S_V = \frac{2}{0{,}89462}\frac{m^3}{min} \times \frac{min}{300\ rev}$ ✓

$S_V = 0{,}00745\ m^3$ ✓

5.2

$P = P_1 V_e \left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$

$P = (102)\left(\frac{2}{60}\right)\left(\frac{1{,}35}{1{,}35-1}\right)\left[\left(\frac{780}{102}\right)^{\frac{1{,}35-1}{1{,}35}} - 1\right]$ ✓

$P = 9{,}109\ kW$ ✓ (3)

5.3

$WD = 9{,}109\ \frac{kJ}{s} \times \frac{min}{300\ rev} \times \frac{60\ s}{1\ min}$ ✓

$WD = 1{,}822\ kJ$ ✓ (3)

[15]

QUESTION 6

6.1 See diagram on page 7.

6.2 6.2.1 32^0 ✓ (1)

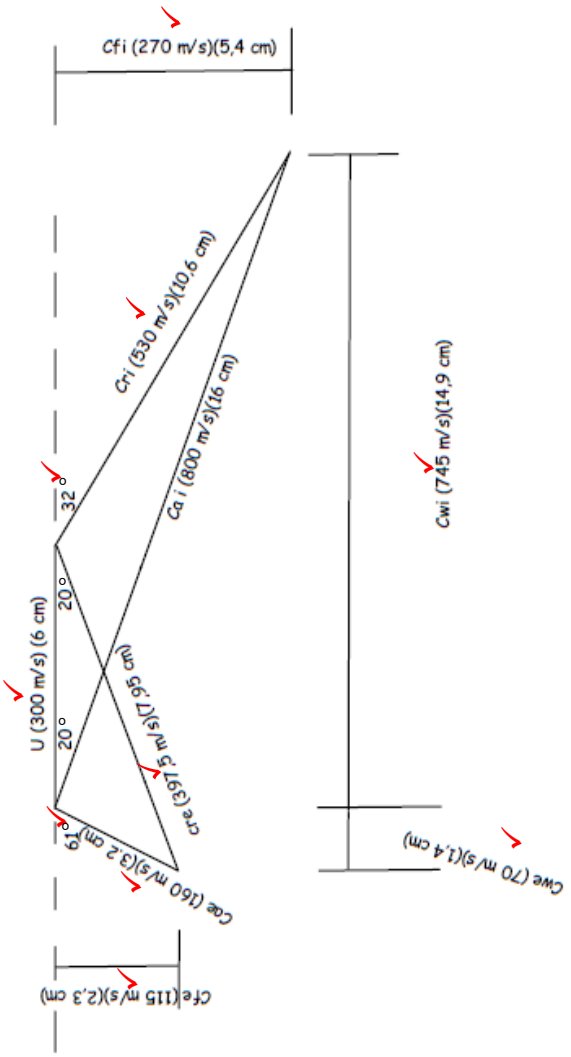
6.2.2 61^0 ✓ (1)

6.2.3 $P = mU\left(C_{we} - (-C_{wi})\right)$

$P = 2 \times 300 \times (70 - (-740))$

$P = 486\ kW$ ✓ (3)

6.1



(10)
[15]

TOTAL: 100

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