higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE (VOCATIONAL)

REFRIGERATION AND AIR CONDITIONING PROCESSES
NQF LEVEL 4

(6030054)

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09:00–12:00

This question paper consists of 6 pages and a formula sheet of 8 pages.

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE (VOCATIONAL)
REFRIGERATION AND AIR CONDITIONING PROCESSES
NQF LEVEL 4
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 black or blue pen.
5. Write neatly and legibly and provide the answer with its SI unit rounded-off to three decimal places where applicable.

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QUESTION 1

1.1 Choose an item from COLUMN B that matches an item in COLUMN A. Write only the letter (A–F) next to the question number (1.1.1–1.1.5) in the ANSWER BOOK.

COLUMN A		COLUMN B	
1.1.1	Flash gases	A	refrigerant controls
1.1.2	Defrost	B	high refrigerating effect
1.1.3	Superheating	C	air conditioning
1.1.4	All air system	D	occurs in TEV
1.1.5	Thermostatic expansion valve	E	removal of ice build-up
		F	pascal

(5 × 1) (5)

1.2 State THREE advantages of the thermostatic expansion valve. (3)

1.3 What is the effect of air in the condenser? (1)

1.4 Give any ONE disadvantage of low humidity. (1)

1.5 Make a neat sketch of a skeleton-pressure enthalpy or P-H diagram indicating the following:

Specific enthalpy (kJ/kg)
Liquid and vapour mixture
Sub-cooled liquid
Absolute pressure (kPa)
Critical point
Superheated vapour
Saturated vapour line
Saturated liquid line
Vapour to liquid line
Liquid to vapour line

(10)
[20]

QUESTION 2

2.1 Saturated air at 14°C at a rate of 44m^3/min is mixed adiabatically with the second outside air stream at 32°C and relative humidity of 60% at a rate of 18m^3/min. Assume that the mixing occurs at atmospheric pressure.

The properties of the respective air streams are as follows:

h_1 = 39.4 kJ/kg dry air
ω_1 = 0.010 kg water/kg dry air
v_1 = 0.826 m^3/kg dry air

and

h_2 = 79.0 kJ/kg dry air
ω_2 = 0.0182 kg water/kg dry air
v_2 = 0.889 m^3/kg dry air

Determine the following:

2.1.1 The mass flow rate of each stream in kg/min. (6)

2.1.2 The mass flow rate of the mixture in kg/min (1)

2.1.3 The humidity ratio of the mixture (3)

2.1.4 The specific enthalpy of the mixture (2)

2.2 The cooling capacity of a refrigeration plant is 35 kW. The coefficient of performance of the plant is 4,9. The refrigerant enthalpy gain in the evaporator is 135 kJ/kg. Calculate:

2.2.1 The refrigerant mass flow rate in kg/s

2.2.2 The work of compression in kJ/kg.

2.2.3 The power required by the compressor motor if the efficiency is 80%

2.2.4 The total amount of heat rejected by the condenser in kJ/kg.

(4 × 2) (8)

[20]

QUESTION 3

3.1 Explain the purposes of the following meters:

3.1.1 Manometer

3.1.2 Anemometer

3.1.3 Pitot tube

3.1.4 Barometer

3.1.5 Velocity meter

(5 × 1) (5)

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3.2 Describe the procedure for conducting a mechanical test (compression test) on a compressor which contains refrigerant. (5)

3.3 What is meant by the *front seat* of a service valve? (1)

3.4 What is meant by *cracking* a service valve? (1)

3.5 Briefly explain why a filter drier is installed in a refrigeration system and indicate in which line it is fitted. (3)

3.6 To operate the cut-in and cut-out on a refrigeration system, two different types of motor controls may be used.

Name these TWO types. (2)

3.7 The two controls in QUESTION 3.6 maintain two conditions, namely temperature limits and cycling time of the unit. To obtain these two conditions, two different control adjustments are used.

Name these TWO adjustments. (2)

3.8 Name any method used to detect a leak in a system. (1)

[20]

QUESTION 4

4.1 What is the function of the overload protector on a domestic fridge compressor? (2)

4.2 In which supply line is the overload protector connected? (1)

4.3 Name FIVE safety devices used for refrigeration systems. (5)

4.4 Three-phase electric motors are generally high kilowatt motors, in other words, they are used for motor of larger sizes.

Explain FOUR advantages of operating on three-phase power supply. (4)

4.5 When a motor is made, the six ends are connected to three terminals.

By means of diagrams, show TWO ways of connecting the windings to a terminal block. (6)

4.6 What will be the result be if a motor is incorrectly connected or wired? (2)

[20]

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QUESTION 5

5.1 Although design faults are not a technician's responsibility, a brief discussion of these is beneficial because a faulty design can definitely cause abnormal running conditions.

5.1.1 Describe FOUR effects of an oversized plant. (4)

5.1.2 Describe FOUR effects of an undersized plant. (4)

5.2 What are the standard procedures to be followed when removing a compressor from a system? (4)

5.3 As refrigeration technician you are called to a site as the plant operator/manager has noticed that the motor only hums when switched on.

5.3.1 Describe FOUR possible causes of this problem. (4)

5.3.2 How can the problem mentioned in QUESTION 5.3.1 be corrected? (4)

[20]

TOTAL: 100

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REFRIGERATION AND AIRCONDITIONING PROCESSES L4

FORMULA SHEET

1. *Density* = $\frac{mass}{volume} \therefore \rho = \frac{m}{v}$ *kg/m*^{3}

   also $\rho = \frac{1}{\upsilon}$ *kg/m*^{3} *(*υ *= specific volume)*

2. *Specific volume* $(\upsilon) = \frac{1}{density} = \frac{1}{\rho}$ *m*^{3}*/kg*

3. *Greek symbols:* η *= Efficiency (neta)*
   ρ *= Density (rho)*

4. *Mass flow rate:* $\left(\dot{m}\right)$

   $\dot{m} = \dot{V} \times \rho$ *kg/s*

   OR $\dot{m} = \dot{V} \times \frac{1}{\upsilon} \therefore \dot{m} = \frac{\dot{V}}{\upsilon}$ *kg/s*

5. *Quantity of heat (Q) (for a change in temperature)*

   $Q = m\,C\Delta T$ *kJ*

   (For a change of phase)

   Q = m.hfg

   (hfg = latent heat required)

   When the heat transfer rate is required, the formula changes to:

   $\dot{Q} = \dot{m}.hfg$ *kJ/s or kW*

6. *Specific enthalpy (h)*

   To calculate the total energy transfer

   $\dot{Q} = \dot{m}\Delta h$ *kJ/s or kW*

7. *Boyle's law:*

   $P_1V_1 = P_2V_2$ *(at constant temperature*

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8. *Charles's law:*

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \text{ (at constant pressure)}$$

9. *Ideal gas law:*

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

10. *The gas constant (R)*

$$R = \frac{P\upsilon}{T} \text{ J/kg.K}$$

11. *Compressor efficiency* = $\frac{\text{Actual displacement } (V)}{\text{Theoretical displacement } (Vp)}$

$$\eta = \frac{V}{Vp} \times \frac{100}{1} = \%$$

12. *Theoretical displacement:*

$$Vp = \frac{\pi \times D^2 \times L \times n \times N}{4} \text{ } m^3/min$$

$$OR = \frac{\pi \times D^2 \times s \times N \times R}{4} \text{ } m^3/min$$

NOTE: (π = 3,142)

13. *Evaporator capacity:*

(a) *The quantity of sensible heat transferred in watts*

(evaporator sensible capacity) $\left(\overset{\circ}{Q}\right)$

$$\overset{\circ}{Q} = U \,.\, A \,.\, \Delta t \text{ watts}$$

(b) *Overall heat transfer coefficient ('U'-factor)*

$$U = \frac{1}{R} \text{ } W/m^2.°C$$

(c) *Resistance of surface to heat flow (R)*

$$R = \frac{1}{U} = \frac{1}{ho} + \frac{x}{k} + \left(\frac{Ao}{A_1} \times \frac{1}{h_1}\right) \text{ } m^2.°C/W$$

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(d) Log mean temperature difference (LMTD):

$$LMTD = \frac{(te - tr) - (t\ell - tr)}{Log\ n\left(\frac{te - tr}{t\ell - tr}\right)}\ °C$$

14. Condenser load:

(a) Total heat rejection of condenser in kW (THR)

$THR = \overset{\circ}{Q}e + \overset{\circ}{Q}i\ kW$

Also THR = refrigeration capacity × heat rejection factor

(b) Condenser capacity $\left(\overset{\circ}{Q}\right)$

$\overset{\circ}{Q} = U\ .\ A\ .\ \Delta t\ kW$

(c) $LMTD = \frac{(tr - t\ell) - (tr - te)}{Log\ n\left(\frac{tr - t\ell}{tr - te}\right)}$

15. The pressure enthalpy diagram:

(a) Refrigerating effect (Re)

$Re = h_1 - h_4\ kJ/kg$

(b) Heat of compression (WD)

$WD = h_2 - h_1\ kJ/kg$

(c) Heat rejection (THR)

$THR = h_2 - h_3\ kJ/kg$

(d) Coefficient of performance (COP):

$COP = \frac{Re}{WD}$ *(cooling)*

$COP = \frac{THR}{WD}$ *(heat pump)*

(e) Refrigerant mass flow $\left(\overset{\circ}{m}\right)$*:*

$\overset{\circ}{m} = \frac{Load}{Re}\ kg/s$

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(f) Plant capacity $= \dot{m} \times \text{Re}\ \ kW$

(g) Theoretical power $= \dot{m} \times WD\ \ kW$

(h) Actual power $= \dfrac{\dot{m} \times WD}{\eta}\ \ kW$

(i) Total heat rejection in kW (THR):

THR in kW = $\dot{m}$ *× THR in kJ/kg kW*

(j) The efficiency of a compressor:

$$\% = \frac{\text{Theoretical power input}}{\text{Actual power input}} \times 100$$

OR

$$\% = \frac{h_2 - h_1}{h_2^1 - h_1} \times 100$$

16. Cooling load calculations:

(a) Basic heat transfer formula

$\dot{Q} = U\ .\ A\ .\ \Delta T$ *watts (J/s)*

(b) To calculate total resistance against heat flow

$$Rt = \frac{1}{h_o} + \frac{d_1}{k_1} + \frac{d_2}{k_2} ... + \frac{1}{h_i}\ \ m^2.°C/W$$

(c) Heat transfer coefficient (U)

$$U = \frac{1}{R_t}\ \ W/m^2.°C$$

(d) Resistance against heat flow (R)

$$R = \frac{d}{k}\ \ m^2.°C/W$$

(e) Total air change in a cold room $\left(\dot{V}\right)$

$$\dot{V} = \frac{V \times f}{86\,400}\ \ m^3/s$$

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(f) Total air change load $\left(\overset{\circ}{Q}\right)$

(i) $\overset{\circ}{Q} = \overset{\circ}{V} \times \rho \times (h_2 - h_1) \times 1\,000$ *watts*

or when using the table for the number of air changes:

(ii) $\overset{\circ}{Q} = \dfrac{V \times f \times \rho \times \Delta h}{86{,}4}$ *watts*

The above formula is the combination of the 2 formulae given in (e) and (f)(i).

(g) The product load:

(i) Sensible heat:

$\overset{\circ}{Q} = \dfrac{\overset{\circ}{m} . C . \Delta t}{86{,}4}$ *watts*

(ii) Latent heat:

$\overset{\circ}{Q} = \dfrac{\overset{\circ}{m}\, \Delta h}{86{,}4}$ *watts*

(iii) Heat respiration:

$\overset{\circ}{Q} = \overset{\circ}{m}\, \Delta h$ *watts*

(h) Miscellaneous loads:

(i) $\text{Equipment load} = \dfrac{\text{Equipment output} \times \text{hours of operation}}{24}$ *watts*

NB: Load and output must be given in watts.

(ii) $\text{Lighting load} = \dfrac{\text{Wattage of lighting} \times \text{hours of operation}}{24}$ *watts*

NB: When lighting is by means of fluorescent lights, add 25% to the lighting load.

(iii) Occupancy load:

$$\overset{o}{Q} = \frac{\text{Heat equivalent per person} \times \text{number of persons} \times \text{hours}}{24} \text{ watts}$$

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17. Ventilation and air conditioning:

(a) Removal of latent heat:

$$\dot{Q} = \dot{m} \times \Delta g \times hfg \ \ kW$$

$$\dot{m} = \frac{\dot{V}}{\upsilon} \ \ kg/s$$

$$\therefore \dot{Q} = \frac{\dot{V} \times \Delta g \times hfg}{\upsilon} \ \ kW$$

(b) Room sensible heat factor (RSHF):

$$RSHF = \frac{RSH}{RSH + RLH} = \frac{RSH}{RTH}$$

(c) Efficiency of an evaporative cooler:

$$\eta = \frac{ta - tc}{ta - tb}$$

(d) Cooling and dehumidification:

$$\dot{Q} = \dot{m}\left[\Delta h - hfg\left(\Delta g\right)\right] \ kW$$

(e) $\dot{V}$ *of the return air*

$$\dot{V}ra = \dot{V}ra - \dot{V}fa \ \ m^3/s$$

(f) Air temperature of mixture in front of coil

$$T = \frac{\left(\dot{v}fa \times tdbfa\right) + \left(\dot{v}ra \times tdbra\right)}{\dot{V}sa} \ °C$$

(g) Quantity of air:

$$\dot{V} = \frac{\dot{Q}}{C \times \rho \times \Delta t} \ \ m^3/s$$

(h) Amount of air forced through an opening by wind:

$$\dot{V} = E \times A \times \upsilon \ \ m^3/s$$

(i) Volume flow due to temperature difference:

$$\dot{V} = kA\sqrt{h\left(\Delta t\right)} \ \ m^3/s$$

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(j) Air changes per hour (f):

$$f = \frac{\overset{\circ}{V} \times 3\,600}{V} \text{ changes/hour}$$

(k) Volume air flow per m^2 opening:

$$\overset{\circ}{V} = \frac{\overset{\circ}{V}}{A} \ m^3/s/m^2$$

(l) Free area of an opening (A):

$$A = \text{total area} \times \eta \ m^2$$

(m) Louvre size for given air speed:

$$= \frac{\overset{\circ}{V} \times 100}{\text{Number of inlets} \times \text{inlet speed} \times \%A} \ m^2$$

18. Fans:

(a) Fan total pressure (Pt)

$$Pt = Ps + Pv \ kPa$$

(b) Theoretical power of the fan:

$$= \overset{\circ}{V} \times Pt \quad kW$$

(c) True power of the fan:

$$= \frac{\overset{\circ}{V} \times Pt}{\eta} \ kW$$

(d) Air power (Ap)

$$Ap = \frac{\overset{\circ}{Q} \times Pt}{N} \ kW$$

(e) Brake power (Bp)

$$Bp = \frac{\overset{\circ}{Q} \times Pt}{\eta t} = \frac{\overset{\circ}{Q} \times Ps}{\eta s}$$

$$\therefore Bp = \frac{Pt}{\eta t} = \frac{Ps}{\eta s} \text{ (for the same volume)}$$

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19. Fan laws:

(a) $$\frac{VOL_1}{VOL_2} = \frac{N_1}{N_2} \times \frac{(DIA_1)^3}{(DIA_2)^3}$$

(b) $$\frac{P_1}{P_2} = \frac{(N_1)^2}{(N_2)^2} \times \frac{(DIA_1)^2}{(DIA_2)^2} \times \frac{\rho_1}{\rho_2}$$

(c) $$\frac{kW_1}{kW_2} = \frac{(N_1)^3}{(N_2)^3} \times \frac{(DIA_1)^5}{(DIA_2)^5} \times \frac{\rho_1}{\rho_2}$$

$$\frac{(DIA_1)}{(DIA_2)} = \frac{N_2}{N_1}$$

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