higher education & training

Department:
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REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

REFRIGERATION TRADE THEORY N3

(11041583)

4 August 2019 (X-paper)
09:00–12:00

Nonprogrammable calculators may be used.

This question paper consists of 7 pages and a formula sheet of 6 pages.

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
REFRIGERATION TRADE THEORY N3
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. Start each question on a new page.
5. Work neatly.

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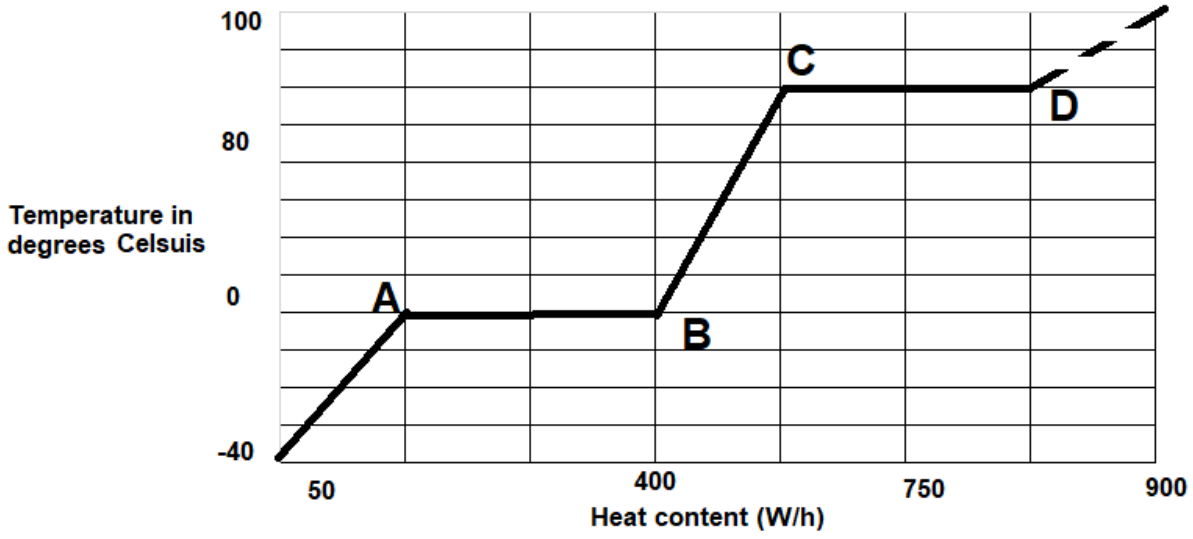
QUESTION 1

1.1 Choose a description from COLUMN B that matches a term in COLUMN A. Write only the letter (A–E) next to the question number (1.1.1–1.1.5) in the ANSWER BOOK.

COLUMN A		COLUMN B	
1.1.1	Heat of condensation	A	solid phase changes to liquid phase
1.1.2	Latent heat of ice	B	liquid phase changes to solid phase without change in temperature
1.1.3	Heat of fusion	C	vapour phase changes to liquid phase
1.1.4	Heat of vaporisation	D	solid (for example dry ice) changes directly from solid phase to a vapour phase
1.1.5	Heat of sublimation	E	liquid phase changes to vapour phase

(5 × 1) (5)

1.2 Complete the following sentence or sentences/paragraph or paragraphs by using the word or words in the list below and referring to the graph. Write only the missing word or words next to the question number (1.2.1–1.2.5) in the ANSWER BOOK.



latent heat; temperature stays the same; melting or fusion; potential energy sensible heat; liquid phase changes to vapor phase; sublimation; heat energy

1.2.1 The process taking place between line A and B … (1)

1.2.2 The process taking place between line B and C… (2)

1.2.3 The condition of the temperature between line A and B… (1)

1.2.4 The type of heat required to raise the temperature of the water between line B and C… (1)

1.2.5 The type of heat required to melt the ice between line A and B… (1)

1.3 State ONE basic thermal law of refrigeration. (3)

1.4 Define each of the following:

1.4.1 Specific heat capacity

1.4.2 Latent heat

1.4.3 Sensible heat

(3 × 2) (6)
[20]

QUESTION 2

2.1 State TWO laws of thermodynamics. (4)

2.2 Draw a labelled block diagram of a vapour compression system indicating each of the following:

- Compressor
- Condenser
- Liquid receiver
- Expansion valve
- Filter dryer
- Evaporator
- Accumulator

Also indicate the direction of the flow of the refrigerant. (8)

2.3 State between which TWO parts the following pipes are connected in a refrigeration system:

2.3.1 Suction pipe

2.3.2 Discharge pipe

2.3.3 Liquid pipe

2.3.4 2-phase pipe

(4 × 2) (8)
[20]

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QUESTION 3

3.1 Draw a neat, labelled sketch of a shell-and-tube condenser (6)

3.2 An 8-cylinder compressor rotating at 20 revolutions per second has a bore of 80 mm and a stroke of 88 mm. It delivers refrigerant at a rate of 0,0225 m^3/s

Calculate the volumetric efficiency of the compressor. (5)

3.3 Study the domestic refrigeration sketch in FIGURE 1 and identify the indicated components by writing the answer next to the letter (A–I) in the ANSWER BOOK.

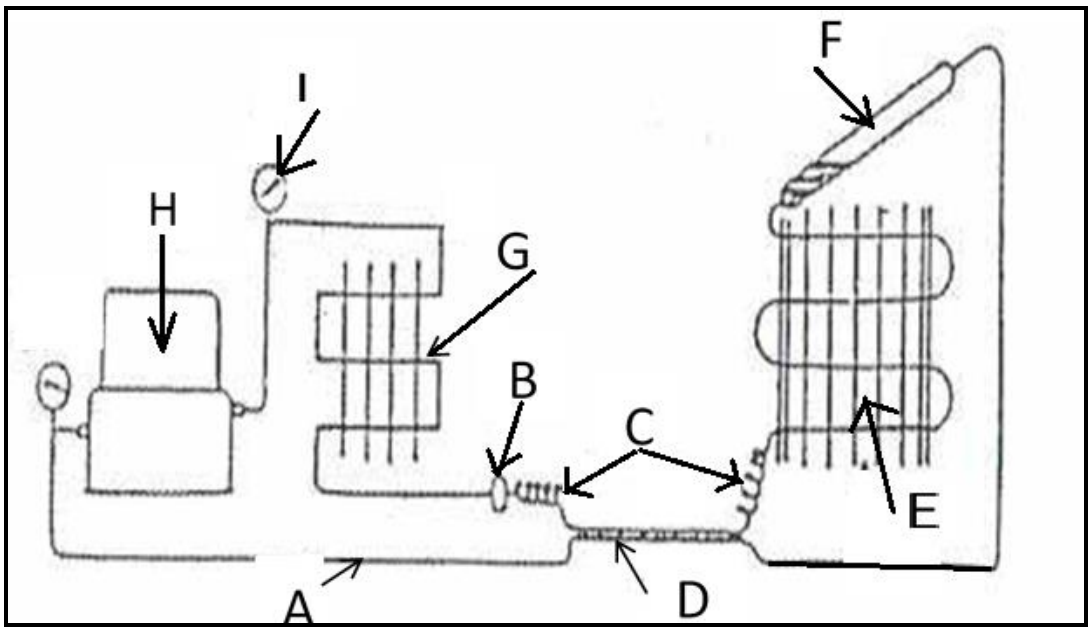

FIGURE 1 (9 × 1) (9)

[20]

QUESTION 4

4.1 Explain each of the following terms:

4.1.1 Operational controls

4.1.2 Safety controls

(2 × 2) (4)

4.2 Identify the type of instruments below and state the purpose of each as used in refrigeration systems. Write only the answer next to the question number (4.2.1–4.2.3) in the ANSWER BOOK.

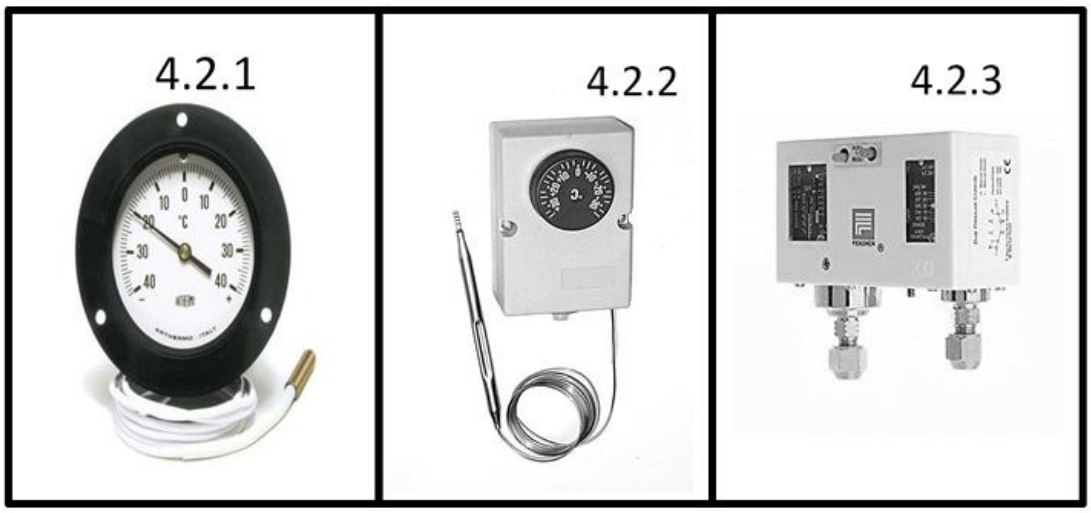

FIGURE 2 (3 × 3) (9)

4.3 4.3.1 Explain the purpose of a filter drier in a refrigeration system. (3)

4.3.2 Is the filter in QUESTION 4.3.1 fitted in the liquid or gas line? (1)

4.4 4.4.1 What type of fan would you install in a large air conditioning plant? (1)

4.4.2 State TWO reasons for the answer in QUESTION 4.4.1. (2)
[20]

QUESTION 5

5.1 Name TWO types of starting relays for fridge compressors. (2)

5.2 Draw a neat, labelled circuit diagram of a capacitor start-capacitor run motor. (5)

5.3 Calculate the capacitance if two capacitors of 15 μF and 30 μF are connected in series. (3)

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5.4 The heat load of a refrigeration system is 30 KW. The enthalpy of the saturated vapour entering the compressor is 80,46 K J/Kg. After compression the enthalpy is 94,06 K J/Kg. The liquid entering the control valve has an enthalpy of 36,16 K J/Kg.

Calculate each of the following:

5.4.1 Refrigerant effect

5.4.2 Work done by compressor

5.4.3 Coefficient of performance (COP)

5.4.4 Refrigerant mass flow rate

5.4.5 Power required to drive compressor if efficiency of plant is 80%

(5 × 2) (10)
[20]

TOTAL: 100

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REFRIGERATION TRADE THEORY N3

FORMULA SHEET

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

   also $\rho = \frac{1}{v}\ kg/m^3 \quad (v = specific\ volume)$

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

3. Greek symbols: $\eta = efficiency\ (neta)$
   $\rho = density\ (rho)$

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

   $\dot{m} = \dot{V} \times \rho \quad Kg/S$

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

5. $(Quantity\ of\ heat\ (Q) for\ a\ change\ in\ temperature)$
   $Q = mC\Delta T\ \ kJ$
   $For\ a\ chnge\ of\ phase)$
   $Q = m.hfg$
   $(hfg = latent\ heat\ required)$
   $when\ the\ heat\ transfered\ rate\ is\ required\ the\ formula\ changes\ to:$
   $\dot{Q} = \dot{m}\ .\ hfg\ KJ/s\ or\ KW$

6. $Specific\ enthalphy\ (h)$

   To calculate the total energy transfer

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

7. $Boyle's\ law:$

   $P_1V_1 = P_2V_2\ (at\ constant\ temperature)$

8. $Charles's\ law:$
   $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

9. $Ideal\ gas\ law:$

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

10. $The\ gas\ constant\ (R)$

    $R = \frac{Pv}{T}\ \ J/Kg.K$

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11. $Compressor\ efficiency = \frac{Actual\ displacement(V)}{Thermal\ displacement(V\rho)}$

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

12. $Theoretical\ displacement$:

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

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

$NOTE: (\pi = 3.142)$

13. $Evaporator\ capacity$:

(a) $The\ quantity\ of\ sensible\ heat\ transferred\ in\ watt$

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

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

(b) $Overall\ heat\ transfer\ coefficient$ (U-factor)

$U = \frac{1}{R}\ \ W/m^2.℃$

(c) $Resistance\ of\ surface\ to\ heat\ flow\ (R)$

$R = \frac{1}{U} = \frac{1}{h_0} + \frac{x}{k} + \left(\frac{Ao}{A_1} + \frac{1}{h_1}\right)\ \ m^2.℃/W$

(d) $Log\ mean\ temperature\ difference\ (LMTD)$

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

14. $Condenser\ \ load$:

(a) $Total\ heat\ rejected\ of\ condenser\ in\ KW(THR)$

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

$Also\ THR = refrigeration\ capacity \times heat\ rejected\ factor$

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

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

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

15. $The\ pressure\ enthalphy\ diagram$:

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(a) $Refrigeration\ effect\ (Re)$
$Re = h_1 - h_4 \quad kJ/kg$

(b) $Heat\ of\ compression\ (WD)$
$WD = h_2 - h_1 \quad kJ/kg$

(c) $Heat\ rejection\ (THR)$
$THR = h_2 - h_3 \quad kJ/kg$

(d) $Coefficient\ of\ performance\ (COP)$:
$COP = \frac{Re}{WD}\ (cooling)$
$COP = \frac{THR}{WD}$ *(heat pump)*

(e) $Refrigerant\ mass\ flow\ \left(\overset{\circ}{m}\right)$
$\overset{\circ}{m} = \frac{Load}{Re}\ kg/s$

(f) $Plant\ capacity = \overset{\circ}{m} \times Re \quad kW$

(g) $Theoretical\ power = \overset{\circ}{m} \times WD \quad kW$

(h) $Actual\ power = \frac{\overset{\circ}{m} \times WD}{\eta} \quad kW$

(i) $Total\ heat\ rejected\ in\ kW\ \ (THR)$
$THR\ in\ kW = \overset{\circ}{m} \times THR\ in\ kJ/kg\ kW$

(j) $The\ efficiency\ of\ a\ compressor$:
$\% = \frac{Theoretical\ power\ input}{Actual\ power\ input} \times 100$
OR
$\% = \frac{h_2 - h_1}{h_{1_2} - h_1} \times 100$

16. $Cooling\ \ load\ calculations$:

(a) $Basic\ heat\ transfer\ formula$
$Q = U\ .A\ .\Delta T\ watts\ (J/S)$

(b) $To\ calculate\ total\ resistance\ against\ heat\ flow$

$Rt = \frac{1}{h_0} + \frac{d_1}{k_1} + \frac{d_2}{k_2} \cdots + \frac{1}{h_1} \quad m^2.℃/W$

(c) $heat\ transfer\ coefficient\ (U)$
$U = \frac{1}{R_1} \quad W/m^2.℃$

(d) $Resistance\ against\ heat\ flow\ (R)$
$R = \frac{d}{k} \quad m^2.℃/W$

(e) $Total\ air\ change\ in\ cold\ room\ \left(\overset{\circ}{V}\right)$
$\overset{\circ}{V} = \frac{V \times f}{86400} \quad m^3/s$

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

(i) $\overset{\circ}{Q} = \overset{\circ}{V} \times \rho \times (h_2 - h_1) \times 1000$ *watts*

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

(ii) $\overset{\circ}{Q} = \frac{V \times f \times \rho \times \Delta h}{86.4}$ *watts*

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

(g) *The product load*:

(i) *Sensible heat*:

$\overset{\circ}{Q} = \frac{\overset{\circ}{m} \cdot C \cdot \Delta t}{86.4}$ *watts*

(ii) *Latent heat*:

$\overset{\circ}{Q} = \frac{\overset{\circ}{m} \Delta h}{86.4}$ *watts*

(iii) *Heat respiration*:

$\overset{\circ}{Q} = \overset{\circ}{m} \cdot \Delta h$ *Watts*

(h) *Miscellaneous loads*:

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

NB: Loadand output must be given in watts

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

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

(iii) *Occupancy load*:

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

17. Ventilation and air conditioning:

(a) *Removal of latent heat*:

$\overset{\circ}{Q} = \overset{\circ}{Q} \times \Delta g \times hfg$ *kW*

$\overset{\circ}{m} = \frac{\overset{\circ}{V}}{v}$ *kg/s*

$\therefore \overset{\circ}{Q} = \frac{\overset{\circ}{V} \times \Delta g \times hfg}{v}$

(i) Sensible heat

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(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*:

$$\overset{\circ}{Q} = \overset{\circ}{m}\ [\Delta h - hfg(\Delta g)]\ kW$$

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

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

(f) *Air temperature of mixture in the front of coil*

$$T = \frac{\left(\overset{\circ}{V}fa \times tdbfa\right) + \left(\overset{\circ}{V}ra \times tdbra\right)}{\overset{\circ}{V}sa}\ ℃$$

(g) *Quantity of air*:

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

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

$$\overset{\circ}{V} = E \times A \times v \quad m^3/s$$

(i) *Volume flow due to temperature difference*:

$$\overset{\circ}{V} = kA\sqrt{h(\Delta t)}\ m^3/s$$

(j) *Air changes per hour* (f):

$$f = \frac{\overset{\circ}{V} \times 3600}{V}\ changes/hour$$

(k) *Volume air low per* m^2 *opening*:

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

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

$A = total\ area \times \eta\ m^2$

(m) *Louvre size for given air speed*:

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

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18. Fans:

(a) *Fan total pressure* (Pt)

$$Pt = Ps + Pv \ \ kPa$$

(b) *Theoretical power of fan* :

$$= \dot{V} \times Pt \ \ kW$$

(c) *True power of fan*:

$$= \frac{\dot{V} \times Pt}{\eta} \ kW$$

(d) *Air power* (Ap)

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

(e) *Brake power* (Bp)

$$Bp = \frac{\dot{Q} \times pt}{\eta\, t} = \frac{\dot{Q} \times ps}{\eta\, t}$$

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

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

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

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