higher education & training

Department:
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REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

REFRIGERATION TRADE THEORY N3

(11041583)

23 November 2022 (X-paper)
09:00–12:00

Nonprogrammable calculators may be used.

This question paper consists of 5 pages and a formula sheet of 7 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. Use only a blue or black pen.
6. Write neatly and legibly.

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QUESTION 1

1.1 Indicate whether the following statements are TRUE or FALSE by writing only 'True' or 'False' next to the question number (1.1.1–1.1.10) in the ANSWER BOOK.

1.1.1 The COP of a domestic refrigerator is less than 1.

1.1.2 Critical temperature is the temperature above which a gas will immediately liquefy.

1.1.3 Presence of moisture in a refrigerant affects the working of the expansion valve.

1.1.4 A thermostatic valve is used as an expansion device by a domestic refrigerator working on the vapour compression cycle.

1.1.5 The bank of tubes at the back of a domestic refrigerator is condenser tubes.

1.1.6 Condensing temperature in a refrigerator is the temperature at which refrigerant gas becomes liquid.

1.1.7 In a flooded evaporator refrigerator, an accumulator at the suction of the compressor is used to superheat the vapour.

1.1.8 The latent heat of refrigerant vaporisation increases at lower temperatures and pressures.

1.1.9 A refrigerant should be a good electric conductor.

1.1.10 In a refrigeration cycle, refrigerant flow is controlled by an expansion valve.

(10 × 1) (10)

1.2 Explain the following two refrigeration systems:

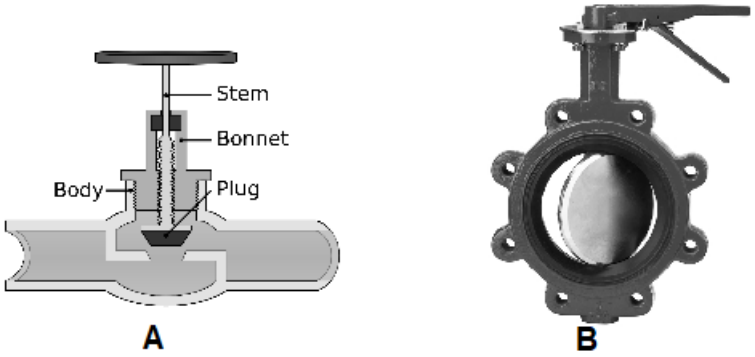
1.2.1 Compound (4)

1.2.2 Cascade (6)

[20]

QUESTION 2

2.1 Name the TWO types of valves (A and B) shown in the FIGURE below. Write only the answer next to the letter (A–B) in the ANSWER BOOK.



A B

(2)

2.2 State the function of the following components/accessories on a water pipe line:

2.2.1 Valve (2)

2.2.2 Strainer (2)

2.2.3 Air vent (2)

2.2.4 Expansion tank (2)

2.3 Make a neat sketch of a skeleton-pressure enthalpy, or P-H diagram with the refrigeration cycle, indicating the following:

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

(10)
[20]

QUESTION 3

3.1 Explain FOUR methods of capacity control on compressors. (8)

3.2 Explain THREE advantages of hermetically sealed compressors. (3)

3.3 An eight-cylinder compressor rotating at 14 r/s has a bore of 80 mm and a stroke length of 90 mm. It delivers refrigerant vapour at a rate of 0,0225 m^3/s under these specifications.

Calculate the volumetric efficiency of the compressor. (5)

3.4 Tabulate the TWO main differences between the *compression system* and the *absorption system.* (4)

3.5 Name TWO methods of compressor lubrication. (2)

3.6 What is meant by the phrase *to crack a service valve*? (2)

[24]

QUESTION 4

4.1 State FOUR basic functions of refrigerant oils. (4)

4.2 Give ONE advantage of using a flooded evaporator. (2)

4.3 Name ONE main functions of the expansion valve. (2)

4.4 Describe the operation principle of the evaporative condenser. (8)

[16]

QUESTION 5

5.1 Define the term *coefficient of performance* (COP). (2)

5.2 The cooling capacity of a refrigeration plant is 45 kW. The coefficient of performance of the plant is 5,4. The refrigerant enthalpy gain in the evaporator is 149 kJ/kg.

Calculate the following:

5.2.1 The refrigerant mass flow rate (2)

5.2.2 The work of compression (2)

5.2.3 The power required by the compressor motor if the efficiency is 85% (2)

5.3 State the TWELVE steps, in sequence, on how to determine the efficiency of an open type refrigeration compressor. (12)

[20]

TOTAL: 100

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REFRIGERATION TRADE THEORY N3

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:*

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

9. *Ideal gas law:*

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

10. *The gas constant (R)*

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

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

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

12. *Theoretical displacement:*

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

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

NOTE: (π = 3,142)

13. *Evaporator capacity:*

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

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

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

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

$$U = \frac{1}{R}\ W/m^2.°C$$

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

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

(d) *Log mean temperature difference (LMTD):*

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

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

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):

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

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

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

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

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

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

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(h) *Actual power* $= \frac{\dot{m} \times WD}{\eta}$ *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*

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

(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

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

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

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

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

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

(g) The product load:

(i) Sensible heat:

$\dot{Q} = \frac{\dot{m} \,.\, C \,.\, \Delta t}{86{,}4}$ *watts*

(ii) Latent heat:

$\dot{Q} = \frac{\dot{m}\, \Delta h}{86{,}4}$ *watts*

(iii) Heat respiration:

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

(h) Miscellaneous loads:

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

NB: Load and output must be given in watts.

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

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

(iii) Occupancy load:

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

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*

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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:

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

(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:

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

(j) Air changes per hour (f):

$$f = \frac{\dot{V} \times 3\,600}{V} \ changes/hour$$

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

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

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

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

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

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

18. *Fans:*

(a) *Fan total pressure (Pt)*

$Pt = Ps + Pv\ \ kPa$

(b) *Theoretical power of the fan:*

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

(c) *True power of the fan:*

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

(d) *Air power (Ap)*

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

(e) *Brake power (Bp)*

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

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

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

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

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