



higher education & training

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NATIONAL CERTIFICATE

REFRIGERATION TRADE THEORY N3

(8190183)

5 April 2018 (X-Paper)
09:00–12:00

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

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. Write neatly and legibly.
-

QUESTION 1

1.1 Various options are given as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question number (1.1.1–1.1.10) in the ANSWER BOOK.

- 1.1.1 The relative coefficient of performance is ...
- A actual COP/theoretical COP.
 - B theoretical COP/actual COP.
 - C theoretical COP $\times$ actual COP.
 - D $1 - (\text{actual COP/theoretical COP})$.
- 1.1.2 In the vapour compression cycle, the condition of the refrigerant is saturated liquid ...
- A before entering the compressor.
 - B before passing the condenser.
 - C after passing through the condenser.
 - D before entering the expansion valve.
- 1.1.3 The boiling point of ammonia is ...
- A 100 °C.
 - B 33,3 °C.
 - C 50 °C.
 - D 0 °C.
- 1.1.4 The vapour compression refrigerator employs the following cycle:
- A Rankine
 - B Carnot
 - C Reversed Rankine
 - D Reversed Carnot
- 1.1.5 The presence of moisture in a refrigerant affects the working of ...
- A heat transfer.
 - B the compressor.
 - C the expansion valve.
 - D the condenser.
- 1.1.6 Air refrigeration operates on the following cycle:
- A Rankine cycle
 - B Erickson cycle
 - C Reversed Carnot cycle
 - D Brayton cycle

- 1.1.7 The higher temperature in a vapour compression cycle occurs at the ...
- A receiver.
 - B expansion valve.
 - C condenser discharge.
 - D compressor discharge.
- 1.1.8 One of the purposes of sub-cooling the liquid refrigerant is to ...
- A reduce compressor overheating.
 - B ensure that only liquid and not the vapour enters the expansion throttling valve.
 - C Increase the cooling effect.
 - D reduce the compressor discharge temperature.
- 1.1.9 The condensing temperature in a refrigerator is the ...
- A temperature of the cooling medium.
 - B temperature of the freezing zone.
 - C temperature at which the refrigerant gas becomes liquid.
 - D condensing temperature of ice.
- 1.1.10 Which ONE of the following is NOT a desirable property of a refrigerant?
- A Having good electrical conductivity
 - B Having a low boiling point
 - C Having a large amount of latent heat
 - D Being non-inflammable

(10 × 1) (10)

1.2 FIGURE 1 below shows a pressure enthalpy (p-h) diagram. Label the parts marked A-J. Write only the answer next to the letter (A-J) in the ANSWER BOOK.

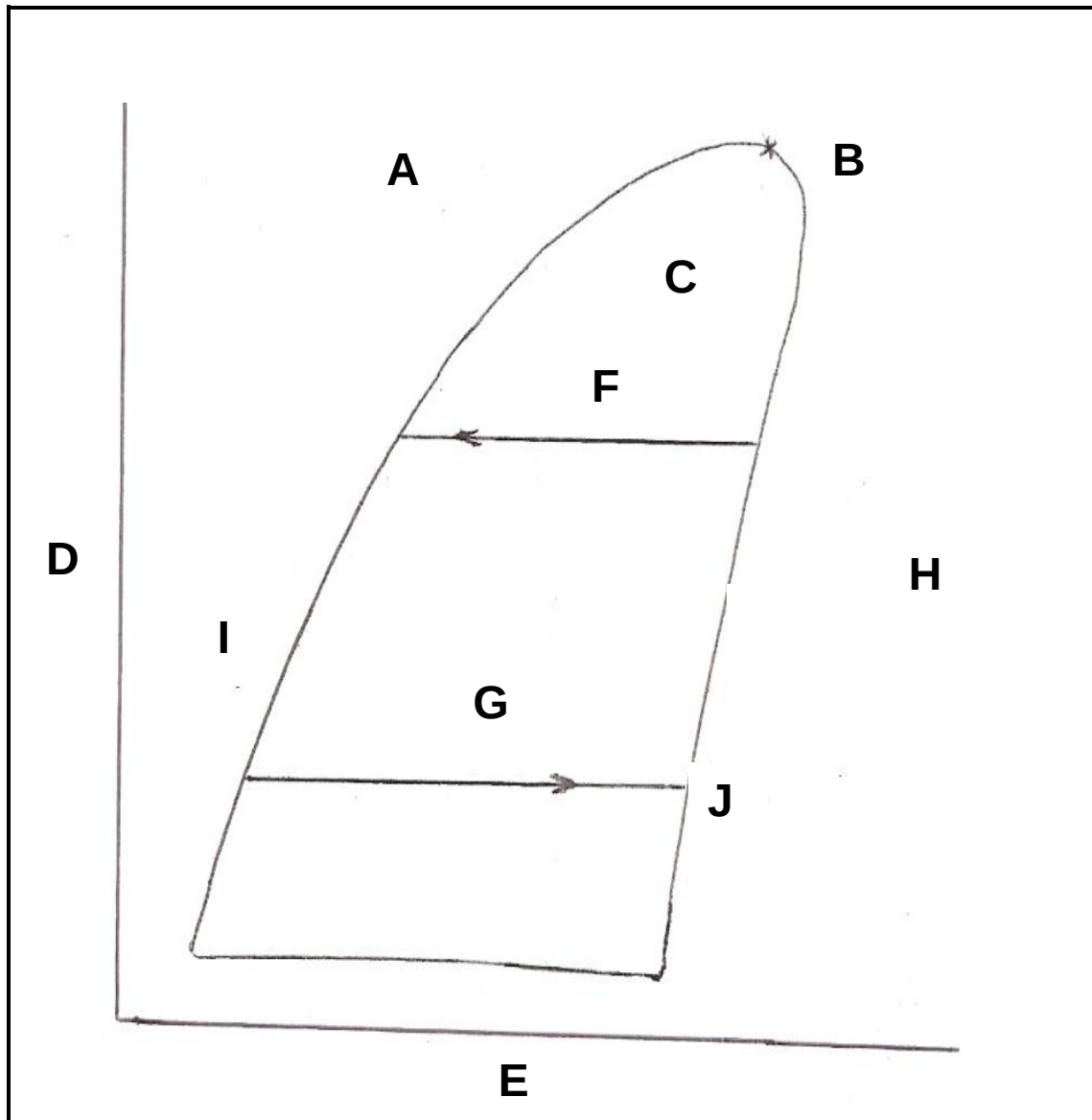


FIGURE 1

$$(10 \times 1)$$

(10)
[20]

QUESTION 2

- 2.1 FIGURE 2 below shows three components X, Y and Z commonly found in a pipe system.

Identify each of the components, and briefly state the use of each component. Write only the answer next to the question 2.1.1-2.1.3 in the ANSWER BOOK.

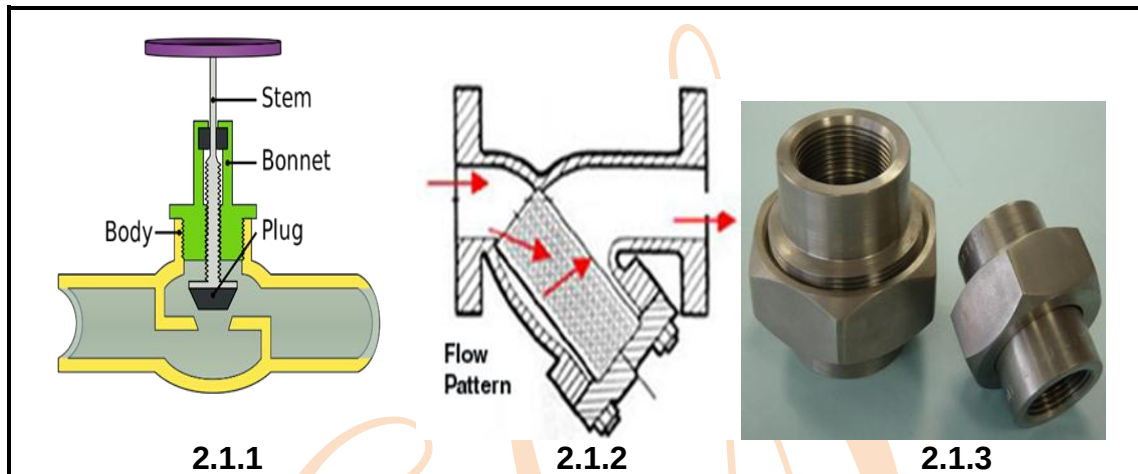


FIGURE 2

(3 × 3)

(9)

- 2.2 FIGURE 3 below shows a type of compressor used in the refrigeration industry.

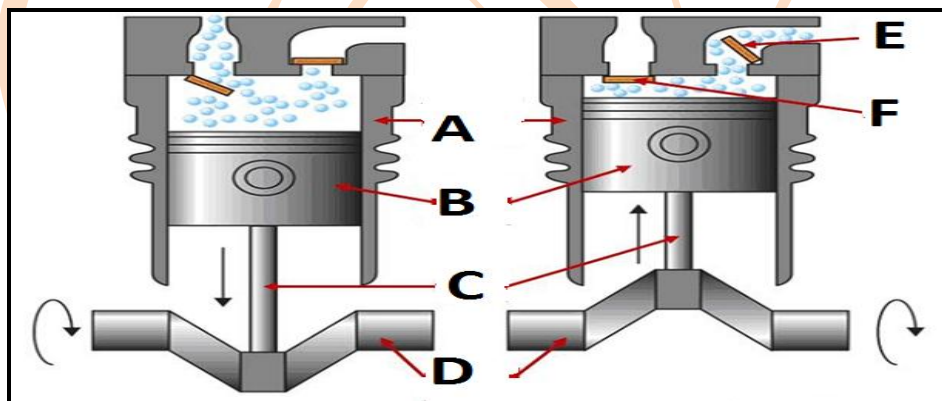


FIGURE 3

- 2.2.1 Identify the type of compressor shown in FIGURE 3 above. (1)
- 2.2.2 Label the parts of the compressor marked A–F. Write only the answer next to the letter (A–F) in the ANSWER BOOK. (6)
- 2.3 State FOUR advantages of using PVC plastic for water piping. (4)
- [20]

QUESTION 3

3.1 Briefly define the following refrigeration terms:

3.1.1 Sub-cooling

3.1.2 Superheating

3.1.3 Volumetric efficiency

3.1.4 Compression ratio

(4 × 2) (8)

3.2 Explain the operation of a current-type starting relay.

(7)

3.3 A six-cylinder compressor rotating at 20 revolutions per second has a bore of 30 mm and a stroke length of 70 mm. It delivers refrigerant vapour at a rate of 0,0043 m³/s under these specifications.

Calculate the volumetric efficiency of the compressor.

(5)
[20]

QUESTION 4

4.1 Name FOUR methods that can be used to control capacity in a condenser.

(4)

4.2 Give TWO advantages and TWO disadvantages of a flooded evaporator.

(4)

4.3 Explain the function of a heat exchanger, as well as where it should be installed in a refrigeration system.

(6)

4.4 State SIX main requirements to be considered in the design and selection of evaporators.

(6)
[20]

QUESTION 5

5.1 Indicate whether the following statements are TRUE or FALSE. Choose the answer and write only 'true' or 'false' next to the question number (5.1.1–5.1.5) in the ANSWER BOOK.

5.1.1 A refrigerant should have a high vapour density.

5.1.2 A refrigerant should have a high enthalpy of vaporisation.

5.1.3 The thermal conductivity of a refrigerant should be high.

5.1.4 A refrigerant should have a low cost.

5.1.5 The specific heat of a refrigerant should be high.

(5 × 1) (5)

5.2 The flashing of gas in liquid lines is a common occurrence that is undesirable in refrigeration.

5.2.1 Define the term *flash gas*. (2)

5.2.2 Name TWO methods that are used to prevent the flashing of gas. (2)

5.2.3 What is the most undesirable effect of the flashing of gas? (1)

5.3



FIGURE 4

5.3 Figure 4 shows a component commonly used in the refrigeration industry. Answer the following questions pertaining to this common component.

5.3.1 Name the component shown in Figure 4. (1)

5.2.2 State the purpose of installing this component. (1)

5.2.3 List FOUR faults occur in the industry that makes the installation of the component in Figure 4 important. (4)

5.4 Give FOUR daily inspections activities done on a reciprocating compressor. (4)

[20]

TOTAL: 100

FORMULA SHEET**REFRIGERATION TRADE THEORY N3**

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

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

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

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

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

$$\overset{\circ}{m} = \overset{\circ}{V} \times \rho \text{ kg/s}$$

$$\text{OR } \overset{\circ}{m} = \overset{\circ}{V} \times \frac{1}{v} \therefore \overset{\circ}{m} = \frac{\overset{\circ}{V}}{v} \text{ kg/s}$$

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

$$Q = m C \Delta T \text{ kJ}$$

(For a change of phase)

$$Q = m.hfg$$

(hfg = latent heat required)

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

$$\overset{\circ}{Q} = \overset{\circ}{m}.hfg \text{ kJ/s or kW}$$

6. Specific enthalpy (h)

To calculate the total energy transfer

$$\overset{\circ}{Q} = \overset{\circ}{m} \Delta h \text{ kJ/s or kW}$$

7. Boyle's law:

$$P_1 V_1 = P_2 V_2 \text{ (at constant temperature)}$$

8. Charles's law:

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

9. Ideal gas law:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

10. The gas constant (R)

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

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

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

12. Theoretical displacement:

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

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

NOTE: ($\pi = 3,142$)

13. Evaporator capacity:

(a) The quantity of sensible heat transferred in watts

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

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

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

$$U = \frac{1}{R} \text{ W/m}^2 \cdot ^\circ\text{C}$$

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

$$R = \frac{1}{U} = \frac{1}{h_o} + \frac{x}{k} + \left(\frac{A_o}{A_i} \times \frac{1}{h_i} \right) \text{ m}^2 \cdot ^\circ\text{C/W}$$

(d) Log mean temperature difference (LMTD):

$$LMTD = \frac{(t_e - t_r) - (t_l - t_r)}{\text{Log } n \left(\frac{t_e - t_r}{t_l - t_r} \right)} \text{ } ^\circ\text{C}$$

14. Condenser load:

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

$$THR = Q_e + Q_i \text{ kW}$$

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

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

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

(c) LMTD = $\frac{(t_r - t_l) - (t_r - t_e)}{\text{Log } n \left(\frac{t_r - t_l}{t_r - t_e} \right)}$

15. The pressure enthalpy diagram:

(a) Refrigerating effect (Re)

$$Re = h_1 - h_4 \text{ kJ/kg}$$

(b) Heat of compression (WD)

$$WD = h_2 - h_1 \text{ kJ/kg}$$

(c) Heat rejection (THR)

$$THR = h_2 - h_3 \text{ kJ/kg}$$

(d) Coefficient of performance (COP):

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

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

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

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

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

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

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

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

$$\text{THR in kW} = \dot{m} \times \text{THR in kJ/kg} \text{ kW}$$

(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

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

(b) To calculate total resistance against heat flow

$$R_t = \frac{1}{h_o} + \frac{d_1}{k_1} + \frac{d_2}{k_2} \dots + \frac{1}{h_i} \text{ m}^2 \cdot ^\circ\text{C/W}$$

(c) Heat transfer coefficient (U)

$$U = \frac{1}{R_t} \text{ W/m}^2 \cdot ^\circ\text{C}$$

(d) Resistance against heat flow (R)

$$R = \frac{d}{k} \text{ m}^2 \cdot ^\circ\text{C/W}$$

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

$$\dot{V} = \frac{V \times f}{86400} \text{ m}^3/\text{s}$$

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

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

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

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

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

(g) The product load:

(i) Sensible heat:

$$\overset{\circ}{Q} = \frac{m \cdot C \cdot \Delta t}{86,4} \text{ watts}$$

(ii) Latent heat:

$$\overset{\circ}{Q} = \frac{m \Delta h}{86,4} \text{ watts}$$

(iii) Heat respiration:

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

(h) Miscellaneous loads:

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

NB: Load and output must be given in watts.

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

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

(iii) Occupancy load:

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

17. Ventilation and air conditioning:

(a) Removal of latent heat:

$$\dot{Q} = \dot{m} \times \Delta g \times h_{fg} \text{ kW}$$

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

$$\therefore \dot{Q} = \frac{\dot{V} \times \Delta g \times h_{fg}}{\nu} \text{ kW}$$

(b) Room sensible heat factor (RSHF):

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

(c) Efficiency of an evaporative cooler:

$$\eta = \frac{t_a - t_c}{t_a - t_b}$$

(d) Cooling and dehumidification:

$$\dot{Q} = \dot{m} [\Delta h - h_{fg} (\Delta g)] \text{ kW}$$

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

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

(f) Air temperature of mixture in front of coil

$$T = \frac{\left(\dot{v}_{fa} \times t_{dbfa} \right) + \left(\dot{v}_{ra} \times t_{dbra} \right)}{\dot{V}_{sa}} \text{ } ^\circ\text{C}$$

(g) Quantity of air:

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

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

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

(i) Volume flow due to temperature difference:

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

(j) Air changes per hour (f):

$$f = \frac{\dot{V} \times 3600}{V} \text{ changes/hour}$$

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

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

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

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

(m) Louvre size for given air speed:

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

18. Fans:

(a) Fan total pressure (P_t)

$$P_t = P_s + P_v \text{ kPa}$$

(b) Theoretical power of the fan:

$$= \dot{V} \times P_t \text{ kW}$$

(c) True power of the fan:

$$= \frac{\dot{V} \times P_t}{\eta} \text{ kW}$$

(d) Air power (A_p)

$$A_p = \frac{Q \times P_t}{N} \text{ kW}$$

(e) Brake power (B_p)

$$B_p = \frac{Q \times P_t}{\eta_t} = \frac{Q \times P_s}{\eta_s}$$

$$\therefore B_p = \frac{P_t}{\eta_t} = \frac{P_s}{\eta_s} \text{ (for the same volume)}$$

19. *Fan laws:*

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

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

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

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

