higher education & training

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NATIONAL CERTIFICATE

REFRIGERATION TRADE THEORY N3

(11041583)

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09:00–12:00

This question paper consists of 7 pages and a formula sheet of 8 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. Write neatly and legibly.

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QUESTION 1

1.1 Indicate whether the following statements are TRUE or FALSE. Choose the answer and write 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 vaporisation of a refrigerant 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 Identify each of the following refrigeration components by writing the answer next to the letter (A–G) in the ANSWER BOOK.

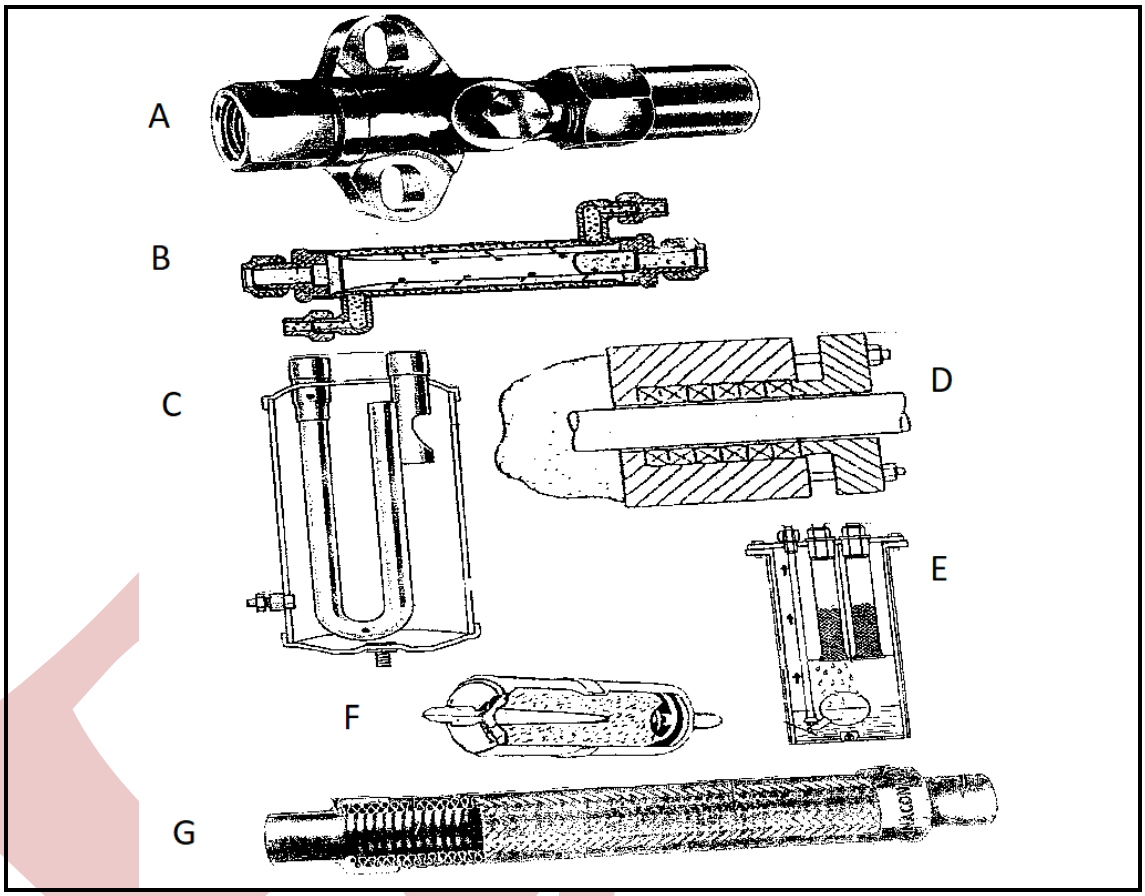

FIGURE 1 (7)

2.2 Draw a neat, labelled sketch of an evaporative condenser. (12)
[19]

QUESTION 3

3.1 The cooling capacity of a refrigeration plant is 50 kW. The coefficient of performance of the plant is 5. The refrigerant-enthalpy gain in the evaporator is 140 kJ/kg.

Calculate:

3.1.1 The refrigerant mass flow rate. (2)

3.1.2 The work of compression. (2)

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

3.1.4 The total amount of heat rejected by the condenser. (2)

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3.2 A defrost thermostat is a commonly installed component in any refrigeration system. Answer the following questions relating to a defrost thermostat

3.2.1 What is the primary function of a defrost thermostat? (2)

3.2.2 List the THREE variables a defrost thermostat works on and briefly explain how it works when using each variable. (3 × 2) (6)

3.3 Steel is commonly used for water piping in refrigeration.

Name THREE types of steel piping that can be used. (3)

3.4 Give ONE disadvantage of a constant-pressure expansion valve. (2)
[21]

QUESTION 4

4.1 State THREE methods that are used to control capacity on DX-evaporators. (3)

4.2 List FOUR basic functions of refrigerant oils. (4)

4.3 State the function of a heat exchanger as well as where it should be installed in a refrigeration system. (6)

4.4 Name THREE possible causes of the following condition and state the corrective measures to be taken:

A compressor fails to start, only hums and trips the overload-protection switch. (3 × 2) (6)

4.5 Give ONE purpose of item E in FIGURE 1 in refrigeration. (1)
[20]

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QUESTION 5

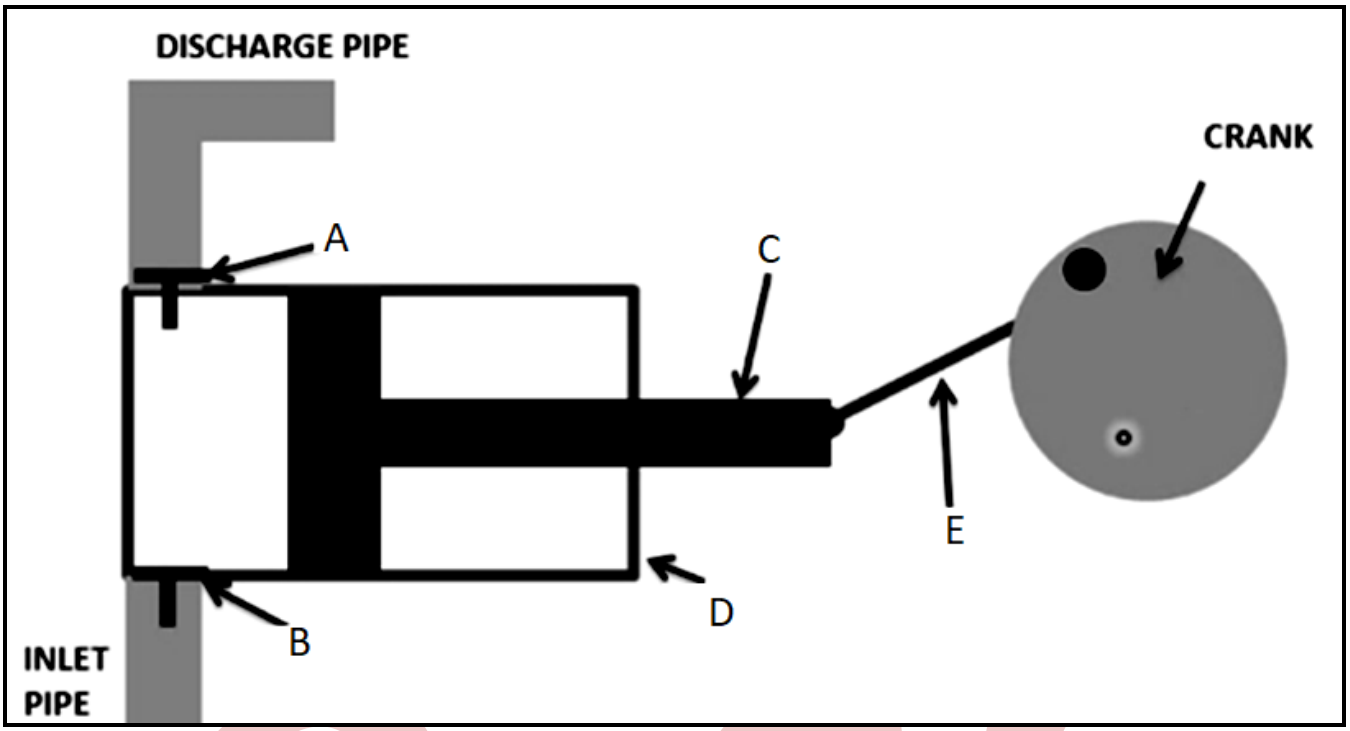

FIGURE 2

5.1 Refer to FIGURE 2 and answer the following questions.

5.1.1 Name the type of pump shown in FIGURE 2. (1)

5.1.2 Label the parts indicated on FIGURE 2 by writing the answer next to the letter (A–E) in the ANSWER BOOK. (5)

5.2 The diagram in FIGURE 3 is applicable to the selection and operation of centrifugal pumps.

Label the curves A, B and C and point D indicated on the diagram by writing the answer next to the letter (A–D) in the ANSWER BOOK. (4)

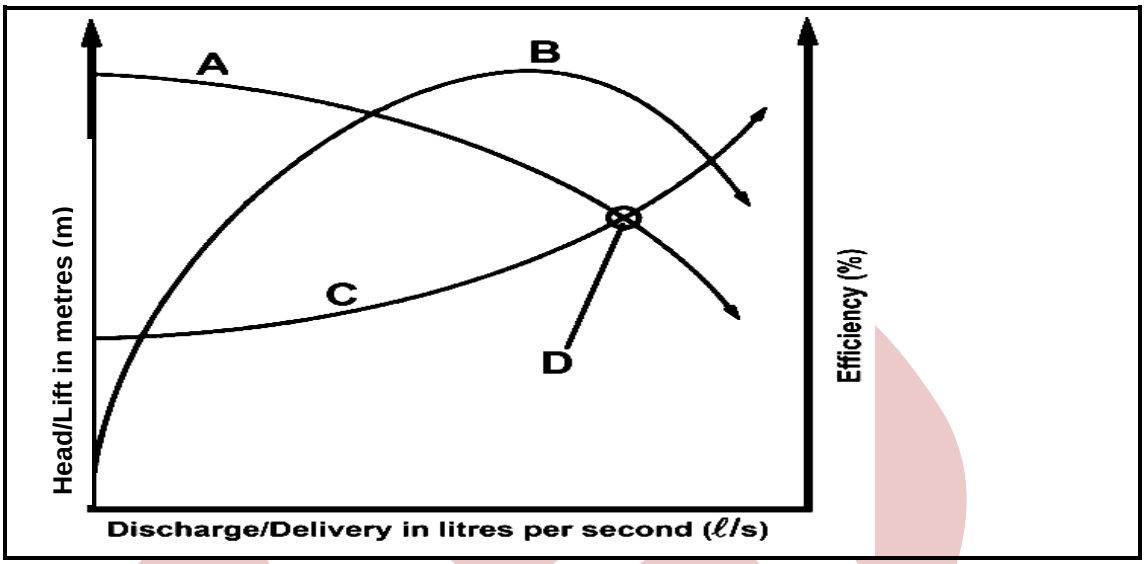

FIGURE 3

5.3 Refer to FIGURE 4, the Crankcase Pressure Regulator and answer the following questions.

5.3.1 A Crankcase Pressure Regulator (CPR) is an outlet pressure regulator and will not allow the crankcase pressure to rise above a predetermined level. Give FIVE considerations that affect its selection for installation and use on a particular refrigeration system. (5)

5.3.2 Figure 4 below shows schematic of a Crankcase Pressure Regulator (CPR). Label the parts by writing the answer next to the letter (A–E) in the ANSWER BOOK. (5)

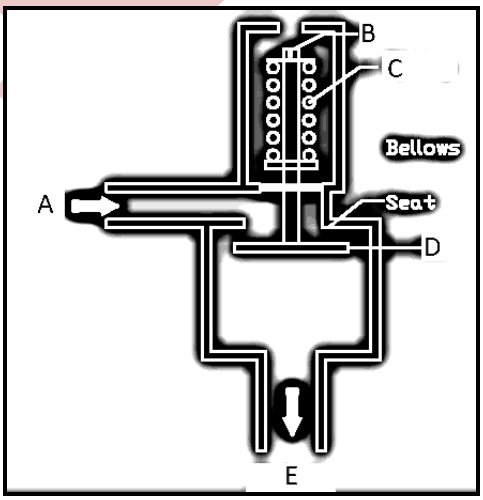

FIGURE 4: Crankcase Pressure Regulator

[20]

TOTAL: 100

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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 = $\frac{Actual\ displacement\ (V)}{Theoretical\ displacement\ (Vp)}$

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

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

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(d) Log mean temperature difference (LMTD):

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

14. Condenser load:

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

$\text{THR} = \overset{\circ}{Q}e + \overset{\circ}{Q}i$ 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) $\text{LMTD} = \frac{(tr - t\ell) - (tr - te)}{Log\, n\left(\frac{tr - t\ell}{tr - te}\right)}$

15. The pressure enthalpy diagram:

(a) Refrigerating effect (Re)

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

(b) Heat of compression (WD)

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

(c) Heat rejection (THR)

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

(d) Coefficient of performance (COP):

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

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

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

$\overset{\circ}{m} = \frac{Load}{\text{Re}}$ 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 = $\frac{\dot{m} \times WD}{\eta}$ 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

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

(c) Heat-transfer coefficient (U)

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

(d) Resistance against heat flow (R)

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

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

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

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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 two formulae given in (e) and (f)(i).

(g) The product load:

(i) Sensible heat:

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

(ii) Latent heat:

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

(iii) Heat respiration:

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

(h) Miscellaneous loads:

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

NB: Load and output must be given in watts.

(ii) 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:

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

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17. Ventilation and air conditioning:

(a) Removal of latent heat:

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

$$\overset{\circ}{m} = \frac{\overset{\circ}{V}}{\upsilon} \text{ kg/s}$$

$$\therefore \overset{\circ}{Q} = \frac{\overset{\circ}{V} \times \Delta g \times hfg}{\upsilon} \text{ kW}$$

(b) Room sensible heat factor (RSHF):

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

(c) Efficiency of an evaporative cooler:

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

(d) Cooling and dehumidification:

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

(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 front of coil:

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

(g) Quantity of air:

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

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

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

(i) Volume flow due to temperature difference:

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

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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:

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

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

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

(m) Louvre size for given air speed:

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

18. Fans:

(a) Fan total pressure (Pt):

$$Pt = Ps + Pv \text{ kPa}$$

(b) Theoretical power of the fan:

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

(c) True power of the fan:

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

(d) Air power (Ap):

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

(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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