Refrigeration and Air-conditioning

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**Air refrigeration system**

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Effective temperature
Load calculation
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Duct Design
Heat Pump and Refrigeration cycles and systems

Objective Questions (IES, IAS, GATE)

Heat Engine, Heat Pump

1. A heat pump works on a reversed Carnot cycle. The temperature in the condenser coils is 27°C and that in the evaporator coils is -23°C. For a work input of 1 kW, how much is the heat pumped?
   (a) 1 kW  
   (b) 5 kW  
   (c) 6 kW  
   (d) None of the above

1. Ans. (c) For heat pump (COP)_HP = \frac{Q_1}{W} = \frac{T_1}{T_1 - T_2} = \frac{300}{300 - 250} or \ Q_1=6xW = 6 \ kW

2. A heat pump is used to heat a house in the winter and then reversed to cool the house in the summer. The inside temperature of the house is to be maintained at 20°C. The heat transfer through the house walls is 7.9 kJ/s and the outside temperature in winter is 5°C. What is the minimum power (approximate) required driving the heat pump?
   (a) 40.5 W  
   (b) 405 W  
   (c) 42.5 W  
   (d) 425 W

2. Ans. (b) (COP)_HP = \frac{Q}{W} = \frac{T_1}{T_1 - T_2} = \frac{293}{293 - 15} or W = \frac{7.9\times15}{293} kW = 405W

4. A refrigerator based on reversed Carnot cycle works between two such temperatures that the ratio between the low and high temperature is 0.8. If a heat pump is operated between same temperature range, then what would be its COP?
   (a) 2  
   (b) 3  
   (c) 4  
   (d) 5

4. Ans. (d) \ \frac{T_2}{T_1} = 0.8 or (COP)_HP = \frac{T_1}{T_1 - T_2} = 5

5. A heat pump for domestic heating operates between a cold system at 0°C and the hot system at 60°C. What is the minimum electric power consumption if the heat rejected is 80000 kJ/hr?
   (a) 2 kW  
   (b) 3 kW  
   (c) 4 kW  
   (d) 5 kW

5. Ans. (b) (COP)_HP = \frac{T_1}{T_1 - T_2} = \frac{273}{273 - 293} or W = \frac{80000}{273 - 293} kW = 3 kW
5. Ans. (c) 
For minimum power consumption,
\[
\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_1 - Q_2}{T_1 - T_2} = \frac{W}{T_1 - T_2}
\]
\[
\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_1 - Q_2}{T_1 - T_2} = \frac{W}{T_1 - T_2}
\]
\[
W = \frac{Q_1}{T_1} \times \frac{T_1 - T_2}{T_1 - T_2} = \frac{80000 \times 333 - 273}{333} = 4\text{ kW}
\]

6. A refrigerator working on a reversed Carnot cycle has a C.O.P. of 4. If it works as a heat pump and consumes 1 kW, the heating effect will be [IES-2003] 
(a) 1 KW  (b) 4 KW  (c) 5 KW  (d) 6 KW 
6. Ans. (c) 
(COP)_{heat pump} = (COP)_{refrigerator} + 1 = 4 + 1 = 5
or (COP)_{heat pump} = \frac{Q_1}{W} = \frac{Heating \, effect}{work \, input}

or Heating effect, \[Q_1 = W \times (COP)_{heat pump} = 5 \text{ kW}\]

12. The coefficient of performance (COP) of a refrigerator working as a heat pump is given by [IES-1992, 1994, 2000; GATE-1995] 
(a) (COP)_{heat pump} = (COP)_{refrigerator} + 2  
(b) (COP)_{heat pump} = (COP)_{refrigerator} + 1  
(c) (COP)_{heat pump} = (COP)_{refrigerator} - 1  
(d) (COP)_{heat pump} = (COP)_{refrigerator}  
12. Ans. (b) The COP of refrigerator is one less than COP of heat pump, if same refrigerator starts working as heat pump i.e. (COP)_{heat pump} = (COP)_{refrigerator} + 1

9. A heat pump operating on Carnot cycle pumps heat from a reservoir at 300 K to a reservoir at 600 K. The coefficient of performance is [IES-1999] 
(a) 1.5  
(b) 0.5  
(c) 2  
(d) 1  
9. Ans. (c) COP of heat pump = \[\frac{T_1}{T_1 - T_2} = \frac{600}{600 - 300} = 2\]

10. Assertion (A): Heat pump used for heating is a definite advancement over the simple electric heater. [IES-1995] 
Reason (R): The heat pump is far more economical in operation than electric heater. 
10. Ans. (b) A and R are right. R is not correct explanation for A.

11. A heat pump is shown schematically as [IES-1994]
11. Ans. (c) In heat pump, heat is rejected to source, work done on compressor, and heat absorbed from sink.

13. A heat pump working on a reversed Carnot cycle has a C.O.P. of 5. If it works as a refrigerator taking 1 kW of work input, the refrigerating effect will be [IES-1993]
(a) 1 kW (b) 2 kW (c) 2 kW (d) 4 kW
13. Ans. (d)

$\text{COP heat pump} = \frac{\text{work done}}{\text{heat rejected}}$ or $\text{heat rejected} = 5 \times \text{work done}$

And heat rejected = refrigeration effect + work input
or $5 \times \text{work input} - \text{work input} = \text{refrigeration effect}$
or $4 \times \text{work input} = \text{refrigeration effect}$

or refrigeration effect = $4 \times 1\text{ kW} = 4\text{ kW}$

15. A building in a cold climate is to be heated by a Carnot heat pump. The minimum outside temperature is -23°C. If the building is to be kept at 27°C and heat requirement is at the rate of 30 kW, what is the minimum power required for heat pump? [IAS-2007]
(a) 180 kW (b) 30 kW (c) 6 kW (d) 5 kW
15. Ans. (d) $(\text{COP})_h = \frac{Q}{W} = \frac{T_1}{T_1 - T_2}$ or $W = Q \left(1 - \frac{T_2}{T_1}\right) = 30 \times \left(1 - \frac{250}{300}\right) = 5\text{ kW}$
16. In the system given above, the temperature $T = 300 \, \text{K}$. When is the thermodynamic efficiency $\eta_E$ of engine $E$ equal to the reciprocal of the COP of $R$?
(a) When $R$ acts as a heat pump
(b) When $R$ acts as a refrigerator
(c) When $R$ acts both as a heat pump and a refrigerator
(d) When $R$ acts as neither a heat pump nor a refrigerator

\[ \eta_E = 1 - \frac{300}{600} = \frac{1}{2} \quad \text{or} \quad \text{COP} = z \]

\[ (\text{COP})_{HP} = \frac{300}{300-150} = z \quad \text{and} \quad (\text{COP})_R = \frac{150}{300-150} = 1 \]

\[ \therefore R \quad \text{must act as a Heat pump} \]

17. Assertion (A): The coefficient of performance of a heat pump is greater than that for the refrigerating machine operating between the same temperature limits.
Reason (R): The refrigerating machine requires more energy for working where as a heat pump requires less.

\[ \text{Ans. (c) } R \text{ is false.} \]

18. In a certain ideal refrigeration cycle, the COP of heat pump is 5. The cycle under identical condition running as heat engine will have efficiency as
(a) zero   (b) 0.20   (c) 1.00   (d) 6.00

\[ \text{Ans. (b) } (\text{COP})_{HE} = \frac{T_1}{T_1-T_2} \quad \text{and} \quad \eta = \frac{T_1-T_2}{T_1} = \frac{1}{(\text{COP})_{HE}} = \frac{1}{5} = 0.2 \]

19. The COP of a Carnot heat pump used for heating a room at 20° C by exchanging heat with river water at 10° C is

\[ \text{Ans. } \text{[IAS-1996]} \]
(a) 0.5    (b) 2.0    (c) 28.3    (d) 29.3

19. Ans. (d) COP = \( \frac{T_1}{T_1 - T_2} = \frac{293}{293 - 283} = 29.3 \)

20. Assertion (A): Although a heat pump is a refrigerating system, the coefficient of performance differs when it is operating on the heating cycle.
Reason (R): It is condenser heat that is useful (the desired effect) instead of the refrigerating effect. 
20. Ans. (a)

21. An industrial heat pump operates between the temperatures of 27°C and -13°C. The rates of heat addition and heat rejection are 750 W and 1000 W, respectively. The COP for the heat pump is

(a) 7.5    (b) 6.5    (c) 4.0    (d) 3.0

21. Ans. (c)

\[
(COP)_{hp} = \frac{Q_1}{Q_1 - Q_2} = \frac{1000}{1000 - 750} = 4
\]

23. Any thermodynamic cycle operating between two temperature limits is reversible if the product of efficiency when operating as a heat engine and the coefficient of performance when operating as refrigeration is equal to 1. 
23. Ans. False
26. In a reversible cycle, the source temperature is 227°C and the sink temperature is
27°C. The maximum available work for a heat input of 100 kJ will be
(a) 100 kJ (b) 60 kJ (c) 40 kJ (d) 88 kJ [IAS-1995]
26. Ans. (c)

Maximum efficiency for 227°C and 27°C sources = \( \frac{500 - 300}{500} = 0.4 \)

\[ \therefore \text{Max work available for a heat input of 100 kJ} = 0.4 \times 100 = 40 \text{ kJ}. \]

Reversed Carnot Cycle

27. A refrigerator works on reversed Carnot cycle producing a temperature of -40°C. Work done per TR is 700 kJ per ten minutes. What is the value of its COP?
(a) 3 (b) 4.5 (c) 5.8 (d) 7.0 [IES-2005]
27. Ans. (a) \( W = \frac{700}{10} \text{ kJ/min}, Q = 210 \text{ kJ/min}, \ COP = \frac{210}{70} = 3 \)

28. The coefficient of performance of a refrigerator working on a reversed Carnot cycle is
4. The ratio of the highest absolute temperature to the lowest absolute temperature is
(a) 1.2 (b) 1.25 (c) 3.33 (d) 4 [IES-1999; IAS - 2003]
28. Ans. (b)

\[ \text{(COP)}_{\text{Refrigerator}} \text{ of reversed Carnot cycle} = \frac{T_2}{T_1 - T_2} = \frac{1}{\frac{T_1 - 1}{T_2}} = 4, \text{ or } \frac{T_1}{T_2} = 0.25 \text{ or } \frac{T_1}{T_2} = 1.25 \]

30. In an ideal refrigeration (reversed Carnot) cycle, the condenser and evaporator
temperatures are 27°C and -13°C respectively. The COP of this cycle would be
(a) 6.5 (b) 7.5 (c) 10.5 (d) 15.0 [IES-1997]
30. Ans. (a) \( \text{COP} = \frac{T_1}{T_2 - T_1} = \frac{(273 - 13)}{(273 + 27) - (273 - 13)} = 6.5 \)

31. A refrigeration system operates on the reversed Carnot cycle. The temperature for
the system is: Higher temperature = 40°C, Lower temperature = 20°C
The capacity of the refrigeration system is 10 TR. What is the heat rejected from
the system per hour if all the losses are neglected? [IAS-2007]
(a) 1·25 kJ/hr (b) 1·55 kJ/hr (c) 2·3 kJ/hr (d) None of the above
31. Ans. (d) \( \text{COP} = \frac{T_2}{T_1 - T_2} = \frac{293}{213 - 293} = \frac{293}{20} = \frac{Q_2}{W} \)

\( Q_2 = 10 \times 14000 \text{ KJ/hr or } W = 14 \times 10^4 \times \frac{20}{293} \text{ KJ/hr} \)

\( Q_1 = Q_2 + W = 14 \times 10^4 + 14 \times 10^4 \times \frac{20}{293} = 14 \times 10^4 \left(1 + \frac{20}{293}\right) \text{ KJ/hr} = 150 \text{ MJ/hr} \)
32. A refrigerating machine working on reversed Carnot cycle takes out 2 kW of heat from the system at 200 K while working between temperature limits of 300 K and 200 K. C.O.P. and power consumed by the cycle will, respectively, be [IES-1997; IAS-2004]
(a) 1 and 1 kW  (b) 1 and 2 kW (c) 2 and 1 kW  (d) 2 and 2 kW
32. Ans. (c) \[ \frac{Q}{W} = \frac{T_1 - T_2}{T_1 - T_2} = \frac{200}{300 - 200} = 2 \]
given \( Q = 2kW \) \( \therefore W = \frac{Q}{2} = 1kW \)

33. A Carnot refrigerator requires 1.5 kW/ton of refrigeration to maintain a region at a temperature of -30°C. The C.O.P. of the Carnot refrigerator is [IES-2003]
(a) 1.42  (b) 2.33  (c) 2.87  (d) 3.26
33. Ans. (b) \[ \text{COP of Carnot refrigerator} = \frac{Q}{W} = \frac{3.5}{1.5} = 2.33 \] \[ \text{As} \text{TR} \approx 3.5kW \]

35. A refrigerating machine working on reversed Carnot cycle consumes 6kW to produce a refrigerating effect of 1000kJ/min for maintaining a region at -40°C. The higher temperature (in degree centigrade) of the cycle will be [IAS-1997]
(a) 317.88  (b) 43.88  (c) 23  (d) zero
35. Ans. (b)
\[ \text{COP} = \frac{Q}{W} = \frac{T_2}{T_1 - T_2} \]
\[ or \frac{(1000 / 60)}{6} = \frac{233}{T_1 - 233} \]
\[ or T_1 - 233 = 83.88 \text{ or } T_1 = 316.88K = 43.88°C \]

36. The C.O.P. of a Carnot refrigeration cycle decreases on [IAS 1994]
(a) decreasing the difference in operating temperatures (b) keeping the upper temperature constant and increasing the lower temperature (c) increasing the upper temperature and keeping the lower temperature constant (d) increasing the upper temperature and decreasing the lower temperature
36. Ans. (c) COP of Carnot refrigerator \[ \frac{T_2}{T_1 - T_2} \] will decrease if upper temperature \( T_1 \) is increased and \( T_2 \) keeping const.

37. The working temperatures in evaporator and condenser coils of a refrigerator are -23°C and 27°C respectively. The COP of the refrigerator is 0.8 of the maximum COP. For a power input of 1 kW, the refrigeration effect produced will be [IES-2001]
(a) 4 kW  (b) 5 kW  (c) 8 kW  (d) 2.5 kW
37. Ans. (a)

39. The efficiency of a Carnot engine is given as 0.75. If the cycle direction is reversed, what will be the value of C.O.P. for the Carnot refrigerator? [IAS-2002]
(a) 0.27  (b) 0.33  (c) 1.27  (d) 2.33
39. Ans. (b)
\[ (COP)_R = (COP)_{HP} \frac{1}{\eta_{Carnot}} = \frac{1}{0.75} - 1 = 0.33 \]
40. A Carnot refrigerator works between the temperatures of 200 K and 300 K. If the refrigerator receives 1 kW of heat the work requirement will be

(a) 0.5 kW  
(b) 0.67 kW  
(c) 1.5 kW  
(d) 3 kW

40. Ans. (a) \[ \text{COP} = \frac{Q}{W} = \frac{T_2}{T_1 - T_2} \quad \text{or} \quad W = \frac{1 \times (300 - 200)}{200} \text{KWW} = 0.5 \text{KW} \]

41. It is proposed to build refrigeration plant for a cold storage to be maintained at –3°C. The ambient temperature is 27°C. If 5 x 10⁶ kJ/h of energy is to be continuously removed from the cold storage, the MINIMUM power required to run the refrigerator will be

(a) 14.3 kW  
(b) 75.3 kW  
(c) 154.3 kW  
(d) 245.3 kW

41. Ans. (c) \[ \text{Maximum COP} = \frac{T_2}{T_1 - T_2} = \frac{270}{300 - 270} = 9 \quad \text{or} \quad W_{\text{min}} = \frac{Q}{9} = \frac{5 \times 10^6}{9 \times 3600} \text{KW} = 154.3 \text{KW} \]

42. If an engine of 40 percent thermal efficiency drives a refrigerator having a coefficient of performance of 5, then the heat input to the engine for each kJ of heat removed from the cold body of the refrigerator is

(a) 0.50kJ  
(b) 0.75kJ  
(c) 1.00 kJ  
(d) 1.25 kJ

42. Ans. (a) \[ \frac{0.4}{Q_1} = \frac{W}{Q_1} \quad \text{(i)} \quad 5 = \frac{Q_2}{W} \quad \text{(ii)} \]

\[ \therefore 0.4Q_1 = \frac{Q_2}{5} \quad \text{or} \quad Q_1 = 0.5Q_2 \]

60. A heat engine with 30% efficiency drives a refrigerator of COP 5.0. What would be the net heat input to the engine for each MW of heat removed in the refrigerator?

(a) 66.67 kJ  
(b) 600 kJ  
(c) 666.67 kJ  
(d) 6600 kJ

60. Ans. (c) For each MW of heat removal in the refrigerator power needed to refrigerator \[ = \frac{1 \text{MW}}{5} = 0.2 \text{MW} \]

For 0.2 MW work output heat engine needed \[ \frac{0.2}{0.3} = 666.67 \text{ kJ/s} \]

62. In the above figure, E is a heat engine with efficiency of 0.4 and R is a refrigerator. Given that \( Q_2 + Q_4 = 3Q_1 \), the COP of the refrigerator is

(a) 2.5  
(b) 3.0  
(c) 4.0  
(d) 5.0

62. Ans. (d) \[ \text{COP} = \frac{Q_3}{Q_2 + Q_4} = \frac{3Q_1}{Q_1} = 3 \]
62. Ans. (d) For heat engine, efficiency = \(1 - \frac{Q_2}{Q_1} = 0.4\) or \(Q_2 = 0.6Q_1\).

And for refrigerator, \(W + Q = Q_4\) or \((Q_1 - Q_2) + Q_3 = Q_4\) or \(Q_1 + Q_3 = Q_2 + Q_4 = 3Q_1\).
Therefore \(2Q_1 = Q_3\).

COP of refrigerator = \(\frac{Q_3}{W} = \frac{Q_3}{Q_1 - Q_2} = \frac{2Q_1}{Q_1 - 0.6Q_1} = 5\).

43. A reversible engine has ideal thermal efficiency of 30%. When it is used as a refrigerating machine with all other conditions unchanged, the coefficient of performance will be \[\text{[IAS-1994, 1995]}\]
(a) 3.33 \hspace{1cm} (b) 3.00 \hspace{1cm} (c) 2.33 \hspace{1cm} (d) 1.33
43. Ans. (c)

45. A Carnot cycle refrigerator operates between 250K and 300 K. Its coefficient of performance is \[\text{[GATE-1999]}\]
(a) 6.0 \hspace{1cm} (b) 5.0 \hspace{1cm} (c) 1.2 \hspace{1cm} (d) 0.8
45. Ans. (b) \(\text{COP}_r = \frac{T_2}{T_1 - T_2} = \frac{250}{300 - 250} = 5\).

46. In the case of a refrigeration system undergoing an irreversible cycle, \(\phi \frac{\delta Q}{T}\) is…
(a) < 0 \hspace{1cm} (b) = 0 \hspace{1cm} (c) > 0 \hspace{1cm} (d) Not sure \[\text{[GATE-1995]}\]
46. Ans. (a)

Liquefaction of Gases
47. Where is an air refrigeration cycle generally employed? \[\text{[IES-2006]}\]
(a) Domestic refrigerators \hspace{1cm} (b) Commercial refrigerators
(c) Air-conditioning \hspace{1cm} (d) Gas liquefaction
47. Ans. (d)

Production of Solid Ice
48. In a vapour compression refrigeration cycle for making ice, the condensing temperature for higher COP \[\text{[IES-2006]}\]
(a) Should be near the critical temperature of the refrigerant
(b) Should be above the critical temperature of the refrigerant
(c) Should be much below the critical temperature of the refrigerant
(d) Could be of any value as it does not affect the COP
48. Ans. (c)

49. Assertion (A): When solid CO\(_2\) (dry ice) is exposed to the atmosphere, it gets transformed directly into vapour absorbing the latent heat of sublimation from the surroundings. \[\text{[IAS-1997]}\]
Reason (R): The triple point of CO₂ is at about 5 atmospheric pressure and at 216 K.

49. Ans. (a)

50. Assertion (A): Quick freezing of food materials helps retain the original texture of food materials and taste of juices. [IES-1994]
Reason (R): Quick freezing causes the formation of smaller crystals of water which does not damage the tissue cells of food materials.
50. Ans. (c) A is true but R is false.

Refrigeration capacity (Ton of refrigeration)

51. Assertion (A): The COP of an air-conditioning plant is lower than that of an ice plant. Reason (R): The temperatures required in the ice plant are lower than those required for an air-conditioning plant. [IAS-1997]
51. Ans. (d) The COP of an air-conditioning plant is higher than that of an ice plant.

52. One ton refrigeration is equivalent to [IES-1999]
(a) 3.5 kW (b) 50 kJ/s (c) 1000 J/min (d) 1000 kJ/min
52. Ans. (a)

53. The power (kW) required per ton of refrigeration is \( N = \frac{Q}{COP} \), where COP is the coefficient of performance, then N is equal to [IAS-2001]
(a) 2.75 (b) 3.50 (c) 4.75 (d) 5.25
53. Ans. (b) \( COP = \frac{Q}{W} \) or \( W = \frac{Q}{COP} \) if Q is in kW, \( Q = \frac{12660}{3600} \) kW = 3.52 kW

54. Round the clock cooling of an apartment having a load of 300 MJ/day requires an air-conditioning plant of capacity about [GATE-1993]
(a) 1 ton (b) 5 tons (c) 10 tons (d) 100 tons
54. Ans. (a) Explanation. 211 kJ/min = 1 T of refrigeration

\[ \text{Refrigeration capacity} = \frac{300 \times 10^3}{24 \times 60 \times 211} \approx 1 \text{ ton} \]

56. In a one ton capacity water cooler, water enters at 30°C at the rate of 200 litres per hour. The outlet temperature of water will be (sp. heat of water =4.18 kJ/kg K)
(a) 3.5°C (b) 6.3°C (c) 23.7°C (d) 15°C [IES-2001; 2003]
56. Ans. (d)

\[ 3.516 \times 3600 = 4.18 \times 200 \times (300 - x) \]
\[ \text{or} \quad x = 14.98°C \approx 15°C \]

57. A refrigerating machine having coefficient of performance equal to 2 is used to remove heat at the rate of 1200 kJ/min. What is the power required for this machine?
(a) 80 kW (b) 60 kW (c) 20 kW (d) 10 kW [IES 2007]
57. Ans. (d) \( COP = \frac{Q}{W} \) or \( W = \frac{Q}{COP} = \frac{1200}{60 \times 2} = 10 \text{ kW} \)

58. A Carnot refrigerator has a COP of 6. What is the ratio of the lower to the higher absolute temperatures? [IES-2006]
58. Ans. (c) \[ (COP)_H = \frac{T_2}{T_1 - T_2} = 6 \text{ or } \frac{T_1}{T_2} = \frac{1}{6} = \frac{7}{6} \text{ or } \frac{T_2}{T_1} = \frac{6}{7} \]

3. A reversed Carnot cycle working as a heat pump has a COP of 7. What is the ratio of minimum to maximum absolute temperatures?  
(a) 7/8  
(b) 1/6  
(c) 6/7  
(d) 1/7

3. Ans. (c) \[ \frac{T_1}{T_2} = \frac{7}{6} \text{ or } \frac{T_1 - T_2}{T_1} = \frac{1}{7} \text{ or } \frac{T_2}{T_1} = \frac{6}{7} \]

59. Which one of the following statements is correct?  
(a) causes corrosion of materials  
(b) reduces heat extraction  
(c) overcools foodstuff  
(d) partially blocks refrigerant flow

59. Ans. (b)

61. Consider the following statements:  
(a) electrical conductivity of materials  
(b) Peltier coefficient  
(c) Seebeck coefficient  
(d) temperature at cold and hot junctions.

Of these statements  
(a) 1, 3, 4 and 5 are correct  
(b) 1, 2, 3 and 5 are correct  
(c) 1, 2, 4 and 5 are correct  
(d) 2, 3, 4 and 5 are correct

61. Ans. (b) In thermoelectric refrigeration, there are no hot and cold junctions.

63. When the lower temperature is fixed, COP of a refrigerating machine can be improved by  
(a) operating the machine at higher speeds  
(b) operating the machine at lower speeds  
(c) raising the higher temperature  
(d) lowering the higher temperature

63. Ans. (d) In heat engines higher efficiency can be achieved when \((T_1 - T_2)\) is higher. In refrigerating machines it is the reverse, i.e. \((T_1 - T_2)\) should be lower.

64. Assertion (A): Power input per TR of a refrigeration system increases with decrease in evaporator temperature.  
Reason (R): C.O.P. of refrigeration system decreases with decrease in evaporator temperature.

64. Ans. (a)

65. In a 0.5 TR capacity water cooler, water enters at 30°C and leaves at 15°C. What is the actual water flow rate?  
(a) 50 litres/hour  
(b) 75 litres/hour  
(c) 100 litres/hour  
(d) 125 litres/hour

65. Ans. (c) \[ Q = mC_p\Delta t \text{ or } 0.5 \times 12660 = m \times 4.2 \times (30 - 15) \text{ or } m = 100\text{kg/hr} \]
Answers with Explanation (Objective)
2. Vapour Compression System

**Objective Questions (IES, IAS, GATE)**

**Modifications in Reversed Carnot Cycle with Vapour as a Refrigerant**

1. The schematic diagram of a vapour compression refrigeration system can be represented as

![Diagram of a vapour compression refrigeration system](image)

1. Ans. (b)

2. In a vapour compression refrigeration plant, the enthalpy values at different points are:
   1. Enthalpy at exit of the evaporator = 350 kJ/kg
   2. Enthalpy at exit of the compressor = 375 kJ/kg
   3. Enthalpy at exit of the condenser = 225 kJ/kg

The refrigerating efficiency of the plant is 0·8. What is the power required per kW of cooling to be produced?

(a) 0·25 kW  (b) 4·0 kW  (c) 12·5 kW  (d) 11 kW

2. Ans. (a)

Refrigerating effect ($Q_o$)

$Q_o = (h_1 - h_4) \times \eta_r$

$Q_o = (350 - 225) \times 0.8$

$Q_o = 100$ kJ/kg

Compressor work ($W$) =

$h_2 - h_1 = 375 - 350 = 25$ kJ/kg
The power required per kW of cooling = \( \frac{W}{Q} = \frac{25}{100} \) kW/kW of cooling

3. The values of enthalpy at the beginning of compression, at the end of compression and at the end of condensation are 185 kJ/kg, 210 kJ/kg and 85 kJ/kg respectively. What is the value of the COP of the vapour compression refrigeration system? [IES-2005]
(a) 0.25 (b) 5.4 (c) 4 (d) 1.35
3. Ans. (c) 

\[
\text{COP} = \frac{(h_1 - h_2)}{(h_2 - h_1)} = \frac{(185 - 85)}{(210 - 185)} = \frac{100}{25} = 4
\]

4. Replacing a water-cooled condenser with an air-cooled one in a vapour compression refrigeration system with constant evaporator pressure results in [IAS-2000]
(a) increase in condensation pressure (b) decrease in pressure ratio (c) increase in pressure ratio (d) increase in condensation temperature
4. Ans. (d)

Heat transfer co-efficient of gas very small compared to water \( h_{\text{water}} >> h_{\text{air}} \) so for same heat transfer temperature difference will be high

\[ Q = h_w A (\Delta T)_w = h_w A (\Delta T)_{air}, \text{so} (\Delta T)_{air} > (\Delta T)_w \]

5. In a vapour compression refrigeration plant, the refrigerant leaves the evaporator at 195 kJ/kg and the condenser at 65 kJ/kg. For 1 kg/s of refrigerant, what is the refrigeration effect? [IES-2005]
(a) 70 KW (b) 100 KW (c) 130 KW (d) 160 KW
5. Ans. (c) 

\[ Q = \dot{m}(h_1 - h_2) = 1 \times (195 - 65) = 130 \text{KW} \]

6. Consider the following statements in respect of absorption refrigeration and vapour compression refrigeration systems: [IES-2003]
1. The former runs on low grade energy.
2. The pumping work in the former is negligible since specific volume of strong liquid solution is small.
3. The latter uses an absorber while former uses a generator.
4. The liquid pump alone replaces compressor of the latter.
Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3 (c) 1 and 4 (d) 2 and 4
6. Ans. (a)

7. A standard vapour compression refrigeration cycle consists of the following 4 thermodynamic processes in sequence: [IES-2002]
(a) isothermal expansion, isentropic compression, isothermal compression and isentropic expansion
(b) constant pressure heat addition, isentropic compression, constant pressure heat rejection and isentropic expansion
(c) constant pressure heat addition, isentropic compression, constant pressure heat rejection and isentropic expansion
(d) isothermal expansion, constant pressure heat addition, isothermal compression and constant pressure heat rejection
7. Ans. (b)
8. For a heat pump working on vapour compression cycle, enthalpy values of the working fluid at the end of heat addition process, at the end of compression process, at the end of heat rejection process, and at the end of isenthalpic expansion process are 195 kJ/kg, 210 kJ/kg, and 90 kJ/kg respectively. The mass flow rate is 0.5 kg/s. Then the heating capacity of heat pump is, nearly

(a) 7.5 kW (b) 45 kW (c) 52.2 kW (d) 60 kW

8. Ans. (d)

9. The enthalpies at the beginning of compression, at the end of compression and at the end of condensation are respectively 185 kJ/kg, 210 kJ/kg and 85 kJ/kg. The COP of the vapour compression refrigeration system is

(a) 0.25 (b) 5.4 (c) 4 (d) 1.35

9. Ans. (c)

10. In a vapour compression plant, if certain temperature differences are to be maintained in the evaporator and condenser in order to obtain the necessary heat transfer, then the evaporator saturation temperature must be

(a) higher than the derived cold-region temperature and the condenser saturation temperature must be lower than the available cooling water temperature by sufficient amounts
(b) lower than the derived cold-region temperature and the condenser saturation temperature must be lower than the available cooling water temperature by sufficient amounts
(c) lower than the derived cold-region temperature and the condenser saturation temperature must be higher than the available cooling water temperature by sufficient amounts
(d) higher than the derived cold-region temperature and the condenser saturation temperature must be higher than the available cooling water temperature by sufficient amounts

10. Ans. (c)

11. The correct sequence of the given components of a vapour compression refrigerator is

(a) evaporator, compressor, condenser and throttle valve
(b) condenser, throttle valve, evaporator and compressor
(c) compressor, condenser, throttle valve and evaporator
(d) throttle valve, evaporator, compressor and condenser

11. Ans. (c)

12. Consider the following statements:

In a vapour compression system, a thermometer placed in the liquid line can indicate whether the
1. refrigerant flow is too low  2. water circulation is adequate.
3. condenser is fouled       4. pump is functioning properly.

Of these statements

(a) 1, 2 and 3 are correct (b) 1, 2 and 4 are correct
(c) 1, 3 and 4 are correct (d) 2, 3 and 4 are correct

12. Ans. (d) Thermometer in liquid line can't detect that refrigerant flow is too low.

13. Consider the following statements:
In the case of a vapour compression machine, if the condensing temperature of the refrigerant is closer to the critical temperature, then there will be

1. excessive power consumption
2. high compression
3. large volume flow.

Of these statements
(a) 1, 2 and 3 are correct  (b) 1 and 2 are correct  (c) 2 and 3 are correct  (d) 1 and 3 are correct

13. Ans. (c) If the condensing temperature of the refrigerant is closer to the critical temperature, compression will be high and large volume flow will take place.

14. A single-stage vapour compression refrigeration system cannot be used to produce ultralow temperatures because

(a) refrigerants for ultra-low temperatures are not available
(b) lubricants for ultra-low temperatures are not available
(c) volumetric efficiency will decrease considerably
(d) heat leakage into the system will be excessive

14. Ans. (a) Refrigerants for ultra-low temperatures are not available

15. In a vapour compression refrigeration system, a throttle valve is used in place of an expander because
(a) it considerably reduces the system weight
(b) it improves the COP, as the condenser is small.
(c) the positive work in isentropic expansion of liquid is very small.
(d) it leads to significant cost reduction.

15. Ans. (c) In a vapour compression refrigeration system, expander is not used because the positive work in isentropic expansion of liquid is so small that it can't justify cost of expander. Thus a throttle valve is used in place of expander.

16. Consider the following statements:

A decrease in evaporator temperature of a vapour compression machine leads to
1. an increase in refrigerating effect
2. an increase in specific volume of vapour
3. a decrease in volumetric efficiency of compressor
4. an increase in compressor work.

Of these statements
(a) 1,3 and 4 are correct  (b) 1,2 and 3 are correct
(c) 2,3 and 4 are correct  (d) 2 and 4 are correct.

16. Ans. (a)

17. Assertion (A): In remote places, the use of absorption refrigeration system plant is more advantageous when compared to vapour compression plant.

Reason (R): The absorption system can use relatively low temperature heat as energy source.

17. Ans. (c) Assertion A is correct but reason is not true. The correct reason should have been that no electricity is required for operation of absorption refrigeration system plant.

18. In a vapour compression refrigeration plant, the refrigerant leaves the evaporator at 195 kJ/kg and the condenser at 65 kJ/kg. For every kg of refrigerant the plant can supply per second, a cooling load of

(a) 70 kW  (b) 100 kW  (c) 130 kW  (d) 160 kW

18. Ans. (c) $h_1 = 195$ kJ/kg and $h_3 = 65$ kJ/kg.

Since there is no heat transfer in throttling, $h_3 = h_4$

Refrigeration effect = $h_1 - h_4 = 195 - 65 = 130$ kJ/kg
19. Consider the following statements:

1. The work of compressor in vapour compression refrigeration system increases with superheat of the suction vapour.
2. The work of compressor depends on the pressure difference rather than the temperature difference of evaporator and condenser.
3. The coefficient of performance is within the range of 3 to 6 except at very low temperature when it may be less than 1.

Which of the statements given above are correct?
(a) 1, 2 and 3  (b) 1 and 2 only  (c) 1 and 3 only  (d) 2 and 3 only

19. Ans. (a)

20. Consider the following statements pertaining to a vapour compression type refrigerator:

1. The condenser rejects heat to the surroundings from the refrigerant.
2. The evaporator absorbs heat from the surroundings to be cooled.
3. Both the condenser and evaporator are heat exchangers with refrigerant as a common medium.
4. The amount of heat exchanged in condenser and evaporator are equal under steady conditions.

Which of the above statements are correct?
(a) 1 and 2  (b) 1, 2 and 3  (c) 1, 2 and 4  (d) 2, 3 and 4

20. Ans. (b)

21. In a vapour compression cycle, the refrigerant, immediately after expansion value is
(a) saturated liquid    (b) subcooled liquid      (c) dry vapour  (d) wet vapour

21. Ans. (d)

In P-h diagram it is point 4’ or 4 both are very wet vapour.

22. Assertion (A): In a vapour compression refrigeration system, the condenser pressure should be kept as low as possible.
Reason (R): Increase in condenser pressure reduces the refrigerating effect and increases the work of compression.

22 Ans. (a)

23. Match List I (T-s diagram) with List II (P-h diagrams) of vapour compression refrigeration cycles and select the correct answer using the codes given below the lists:
23. Ans. (b)

24. Theoretical vapour compression refrigeration cycle is represented on a T-s diagram as

[IAS-1997]

24. Ans. (c)

25. In an ideal vapour compression refrigeration cycle, the enthalpy of the refrigerant before and after the evaporator are respectively 75 kJ/hg and 180 kJ/kg. The circulation rate of the refrigerant for each ton of refrigeration is

[IAS-1997]

(a) 1 kg/min   (b) 2 kg/min   (c) 3 kg/min   (d) 4 kg/min

25. Ans. (b) \[ Q = m (h_1 - h_4) = m (180 - 75) = 211 \] or \[ m = \frac{211}{105} \approx 2 \text{ kg/min} \]
26. In an ideal vapour compression refrigeration cycle, the enthalpy of the refrigerant at exit from the condenser, compressor and evaporator is 80 kJ/kg, 200 kJ/kg and 180 kJ/kg respectively. The coefficient of performance of the cycle is

(a) 6  (b) 5  (c) 3.5  (d) 2.5  

IAS-1996

Ans. (b) $h_3 = h_4 = 80$ kJ/kg

$h_1 = 180$ kJ/kg and $h_2 = 200$ kJ/kg

$\text{WC} = h_2 - h_1 = 200 - 180 = 20$ KJ/kg

$\text{Q} = h_1 - h_4 = 180 - 80 = 100$ KJ/kg

$\text{COP} = \frac{Q}{\text{WC}} = \frac{100}{20} = 5$

27. The correct sequence of vapour compression (VC), vapour absorption (VA) and steam ejector (SE) refrigeration cycles in increasing order of the C.O. P is

(a) VC, VA, SE  (b) VA, SE, VC  (c) SE, VC, VA  (d) SE, VA, VC

IAS-1995

Ans. (b) The correct sequence of VC, VA and SE in increasing order of COP is VA, SE and VC, the Value being of the order of 0.3 to 0.4 0.5 to 0.8 and 4 to 5 respectively.

28. The vapour compression refrigeration cycle is represented as shown in the figure below, with state 1 being the exit of the evaporator. The coordinate system used in this figure is

(a) p-h  (b) T-s  (c) p-s  (d) T-h

GATE-2005

Ans. (a)

29. In a vapour compression refrigeration system, liquid to suction heat exchanger is used to

(a) Keep the COP constant  
(b) prevent the liquid refrigerant from entering the compressor  
(c) subcool the liquid refrigerant leaving the condenser  
(d) subcool the vapour refrigerant from the evaporator

GATE-2000

Ans. (c)

Data for Q. 30 – 31 are given below. Solve the problems and choose correct answers.

A refrigerator based on ideal vapour compression cycle operates between the temperature limits of -20°C and 40°C. The refrigerant enters the condenser as saturated vapour and leaves as saturated liquid. The enthalpy and entropy values for saturated liquid and vapour at these temperatures are given in the table below.
30. If refrigerant circulation rate is 0.025 kg/s, the refrigeration effect is equal to
(a) 2.1 kW  (b) 2.5 kW  (c) 3.0 kW  (d) 4.0 kW  \[\text{GATE-2003}\]
30. Ans. (a)

31. The COP of the refrigerator is
(a) 2.0  (b) 2.33  (c) 5.0  (d) 6.0  \[\text{GATE-2003}\]
31. Ans. (b)

<table>
<thead>
<tr>
<th>T(°C)</th>
<th>h_i(kJ/kg)</th>
<th>h_f(kJ/kg)</th>
<th>s_i(kJ/kg K)</th>
<th>s_f(kJ/kg K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20</td>
<td>20</td>
<td>180</td>
<td>0.07</td>
<td>0.7366</td>
</tr>
<tr>
<td>40</td>
<td>80</td>
<td>200</td>
<td>0.3</td>
<td>0.67</td>
</tr>
</tbody>
</table>

32. A refrigerating system operating on a reversed Brayton refrigeration cycle is used for maintaining 250K. If the temperature at the end of constant pressure cooling is 300 K and rise in the temperature of air in the refrigerator is 50 K, then the net work of compression will be (assume air as the working substance with \(c_p = \text{kJ per kg per K}\))
(a) 250 kJ/kg  (b) 200 kJ/kg  (c) 50kJ/kg  (d) 25kJ/kg  \[\text{IES-1993}\]
32. Ans. (d) Figure shows the reversed Brayton refrigeration cycle. Various values are shown. Net work of compression = \((h_2 - h_1) - (h_3 - h_4)\)
Now \(\frac{T_2}{T_1} = \frac{T_3}{T_4}\)

or \(T_2 = \frac{300}{200} \times 250 = 375\)

Net work = \((375 - 250) - (300 - 200) = 25\) and Net work = \(25 \times C_p = 25\) kJ/kg

33. Match List-I (Effect) with List-II (Process) in the case of an ideal refrigeration cycle and select the correct answer using the codes given below the Lists:

<table>
<thead>
<tr>
<th>List-I</th>
<th>List-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Work input</td>
<td>1. Constant pressure at higher temperature</td>
</tr>
<tr>
<td>B. Heat rejection</td>
<td>2. Isentropic compression</td>
</tr>
<tr>
<td>C. Expansion</td>
<td>3. Constant temperature at lower pressure</td>
</tr>
<tr>
<td>D. Heat absorption</td>
<td>4. Adiabatic</td>
</tr>
</tbody>
</table>

Codes: (a) 4 1 2 3 (b) 2 3 4 1 (c) 2 1 4 3 (d) 4 2 3 1

33. Ans. (c)

**Actual Vapour Compression Cycle**

34. Assertion (A): Subcooling of refrigerant liquid increases the coefficient of performance of refrigeration. [IES-2004]
Reason (R): Subcooling reduces the work requirement of a refrigeration cycle.
34. Ans. (c) Sub cooling ↑ Refrigerating effect thus ↑ COP but has no effect on compressor work \(W_c\).

35. Subcooling heat exchanger is used in a refrigeration cycle. The enthalpies at condenser outlet and evaporator outlet are 78 and 182 kJ/kg respectively. The enthalpy at outlet of isentropic compressor is 230 kJ/kg and enthalpy of subcooled liquid is 68 kJ/kg. The COP of the cycle is [IES-2002]

(a) 3.25 (b) 2.16 (c) 3.0 (d) 3.5

35. Ans. (c)

36. The performance of an evaporator condenser largely depends on [IES-1999]
(a) dry bulb temperature of air (b) wet bulb temperature of air
(c) hot water temperature (d) air-conditioned room temperature

36. Ans. (a)

37. Which one of the following is the p-v diagram for air refrigeration cycle?
37. Ans. (a)

38. Match items in List I with those in List II and III and select the correct answer.

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
<th>List III</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Subcooling</td>
<td>2. Evaporator</td>
<td>7. Increase in refrigerating effect.</td>
</tr>
</tbody>
</table>

Code: A B C D  A B C D
(a) 3,10 1,7 2,9 4,6 (b) 5,8 1,7 2,10 4,9 (c) 4,10 3,8 3,10 1,6 (d) 2,7 5,8 4,6 1,9

38. Ans. (b) Reversed Carnot engine is used for heat pump and it has highest COP. Thus for A, the correct choice from List II and List III is 5, 8. Subcooling occurs in condenser and it increases refrigeration effect. Therefore for B, the correct choice from List II and III is 1, 7.
Superheating occurs in evaporator and it is involved in dry compression. Thus for Part C in List I, the correct choice from Lists II and III is 2, 10. Constant enthalpy process takes place during throttling and is basically adiabatic process. This D is matched with 4,9.

39. The figure given above depicts saturation dome for water on the temperature-entropy plane. What is the temperature difference $\Delta T$ shown on a typical isobar line known as?
(a) Degree of wet bulb depression
(b) Degree of saturation
(c) Degree of sub cooling
(d) Degree of reheat

39. Ans. (c)
40. The operating temperature of a cold storage is -2°C. Heat leakage from the surrounding is 30 kW for the ambient temperature of 40°C. The actual COP of the refrigeration plant used is one-fourth that of an ideal plant working between the same temperatures. The power required to drive the plant is [IES-1994]

(a) 1.86 kW  (b) 3.72 kW  (c) 7.44 kW  (d) 18.60 kW

40. Ans. (d) COP of ideal plant working between limits -2 and 40°C, i.e. 271 and 313 K is \[ \frac{T_1}{T_2-T_1} = \frac{271}{313-271} = 6.45 \], so COP of refrigeration plant = 6.45/4 = 1.61

\[ \text{COP} = \frac{\text{heat abstracted}}{\text{Work required}} \quad \text{or} \quad \text{Work required} = \frac{30}{1.61} = 18.60 \text{ kW} \]

41. Consider the following steps: [IES-1994]

1. Starting of compressor
2. Starting of cooling tower pump.
3. Starting of chiller water pump
4. Starting of blower motor of cooling coil.

The correct sequence of these steps in the starting of a cell air-conditioning plant using chilled water cooling coil, is (a) 3,1,4,2  (b) 1,3,2,4  (c) 3,2,1,4  (d) 1,3,4,2

41. Ans. (c) The correct sequence in starting of a central air conditioning plant using chilled water cooling coil is starting of chiller water pump, starting of cooling tower pump, starting the compressor, starting of blower motor of cooling coil.

42. A refrigerator storage is supplied with 3600 kg of fish at a temperature of 27°C. The fish has to be cooled to -23°C for preserving it for a long period without deterioration. The cooling takes place in 10 hours. The specific heat of fish is 2·0 kJ/kgK above freezing point of fish and 0·5 kJ/kgK below freezing point of fish, which is -3°C. The latent heat of freezing is 230 kJ/kg. What is the power to drive the plant if the actual COP is half that of the ideal COP? [IAS-2002]

(a) 30 kW  (b) 15 kW  (c) 12 kW  (d) 6 kW

42. Ans. (c) \( (COP)_{\text{actual}} = \frac{1}{2} (COP)_{\text{ideal}} = \frac{1}{2} \times \frac{250}{300-250} = 2.5 \)

Total Heat transfer \( (Q) = m.c_p_e (\Delta T)_{\text{before freeze}} + m.c_p_e (\Delta T)_{\text{after freeze}} \)

\( = 3600 [2 \times 30 + 230 + 0.5 \times 20] kJ = 3600 \times 300 kJ \)

Rate of heat transfer \( \frac{Q}{t} = \frac{3600 \times 300}{10 \times 3600} = 30 kW \)

\( \text{COP} = \frac{\dot{Q}}{W} \quad \text{or} \quad \frac{\dot{Q}}{\text{COP}} = \frac{30}{2.5} = 12 kW \)

43. Consider the following statements: [IAS-1999]

High condenser pressure in a refrigeration system can occur because
1. the water flow rate is lower than the desired value.
2. non-condensable gases are present in the system
3. of accumulation of lubricating oil in condenser
4. of low charge of refrigerant in the system.

Of these statements
(a) 1, 3 and 4 are correct  (b) 1, 2 and 3 are correct  (c) 1, 2 and 4 correct  (d) 2, 3 and 4 are correct
43. Ans. (b)

44. Excessive pressure drop in liquid line in a refrigerating system causes
(a) high condenser pressure   (b) flashing of the liquid refrigerant
(c) higher evaporator pressure  (d) under cooling of the liquid refrigerant
44. Ans. (b)

45. In system A vapour are superheated by 10°C in the evaporator while in system B
vapour are superheated by 10°C in a liquid vapour regenerative heat exchanger, other
conditions being the same. Then
(a) C.O.P. of A = C.O.P. of B
(b) C.O.P. of both A and B > C.O.P. of Reversed Carnot Cycle
(c) C.O.P. of A > C.O.P. of B
(d) C.O.P. of A < C.O.P. of B
45. Ans. (a)

\[ h_v - h_l = h_3 - h_5 \]

For regeneration as \[ h_v - h_a = h_4 - h_4' \]

∴ COP is same

Heat Pump

Second Law Efficiency of Vapour Compression Cycle
Answers with Explanation (Objective)
Refrigerants

Objective Questions (IES, IAS, GATE)

1. A good refrigerant should have
   (a) large latent heat of vaporisation and low operating pressures
   (b) small latent heat of vaporisation and high operating pressures
   (c) large latent heat of vaporisation and large operating pressures
   (d) small latent heat of vaporisation and low operating pressures
   Ans. (a)

2. The desirable combination of properties for a refrigerant include
   (a) high specific heat and low specific volume
   (b) high heat transfer coefficient and low latent heat
   (c) high thermal conductivity and low freezing point
   (d) high specific heat and high bailing point
   Ans. (a) High thermal conductivity enables better heat transfer in evaporator and condenser. Lower specific volume implies smaller compressor can be used and refrigerating effect per kg of refrigerant increases.

3. Match List II with List II and select the correct answer using the codes given below the lists:

<table>
<thead>
<tr>
<th>List I (Refrigerant)</th>
<th>List II (Principal application)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Air</td>
<td>1. Direct contact freezing of food</td>
</tr>
<tr>
<td>B. Ammonia</td>
<td>2. Centrifugal compressor system</td>
</tr>
<tr>
<td>C. Carbon dioxide</td>
<td>3. Large industrial temperature installation</td>
</tr>
<tr>
<td>D. Refrigerant-II</td>
<td>4. Automotive air-conditioners</td>
</tr>
<tr>
<td></td>
<td>5. Aircraft refrigeration</td>
</tr>
<tr>
<td>Code: A B C D</td>
<td>A B C D</td>
</tr>
<tr>
<td>(a) 4 3 1 2</td>
<td>(b) 5 3 1 2</td>
</tr>
<tr>
<td>(c) 2 4 3 5</td>
<td>(d) 5 3 2 1</td>
</tr>
</tbody>
</table>

3. Ans. (b)

4. Which of the following statements are true for Ammonia as a refrigerant?
   1. It has higher compressor discharge temperature compared to fluorocarbons.
   2. It is toxic to mucous membranes.
   3. It requires larger displacement per TR compared to fluorocarbons.
   4. It reacts with copper and its alloys.
   Select the correct answer using the codes given below:

<table>
<thead>
<tr>
<th>Codes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) 1 and 2</td>
</tr>
<tr>
<td>(b) 1, 2 and 3</td>
</tr>
<tr>
<td>(c) 1, 2 and 4</td>
</tr>
<tr>
<td>(d) 2, 3 and 4</td>
</tr>
</tbody>
</table>

4. Ans. (c)
5. A good refrigerant should have:
(a) High latent heat of vaporization and low freezing point
(b) High operating pressure and low freezing point
(c) High specific volume and high latent heat of vaporization.
(d) Low COP and low freezing point.
5. Ans. (a)

6. Which of the following refrigerant has the maximum ozone depletion in the stratosphere?
(a) Ammonia   (b) Carbon dioxide  (c) Sulphur dioxide  (d) Fluorine
6. Ans. (d)

Designation of Refrigerants

8. Consider the following statements regarding refrigerants:
1. Refrigerant NH₃ is used in reciprocating compressors.
2. Refrigerant CO₂ is used in reciprocating compressors.
3. Refrigerant R-11 is used in centrifugal compressors.
Which of these statements are correct?
(a) 1 and 3   (b) 1 and 2    (c) 2 and 3   (d) 1, 2 and 3
8. Ans. (d)

9. Environment friendly refrigerant R134a is used in the new generation domestic refrigerators. Its chemical formula is
(a) CH ClF₂  (b) C₂ Cl₃ F₃  (c) C₂ Cl₂ F₄  (d) C₂ H₂ F₄
9. Ans. (d)

Hence answer is, C₂H₂F₄.

10. Match List-I (Refrigerant) with List-II (Chemical constituent) and select the correct answer using the codes given below the lists:

List-I (Refrigerant) List -II (Chemical constituent)
A. R-12 1. Trichlorotrifluoroethane (CCl₂FCClF₂)
B. R-22 2. Difluoro monochloro methane (CHF₂Cl)
C. R-717 3. Ammonia (NH₃)
D. R-113 4. Difluoro dichloro methane (CCl₂F₂)

Codes: A B C D A B C D
(a) 3 2 4 1 (b) 4 2 3 1
(c) 3 1 4 2 (d) 4 1 3 2
10. Ans. (b)
11. Match List I (Chemical formula of refrigerant) with List II (Numerical Designation) and select the correct answer using the codes given below the lists:

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
<th>[IAS-2002]</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Chemical formula of refrigerant)</td>
<td>(Numerical Designation)</td>
<td></td>
</tr>
<tr>
<td>A. NH₃</td>
<td>1. 12</td>
<td></td>
</tr>
<tr>
<td>B. CCl₂F₂</td>
<td>2. 22</td>
<td></td>
</tr>
<tr>
<td>C. CHClF₂</td>
<td>3. 40</td>
<td></td>
</tr>
<tr>
<td>D. CCl₂ FCCl F₂</td>
<td>4. 113</td>
<td>5. 717</td>
</tr>
</tbody>
</table>

Codes: A  B  C  D   A  B  C  D
(a) 4  1  5  2   (b) 5  3  2  4
(c) 4  3  5  2   (d) 5  1  2  4

11. Ans. (d) \(R(C-1)(H+1)F\) and Cl by balance
And for inorganic refrigerant \(R\) (700+Molecular weight)

12. Match List I with List II and select the correct answer using the codes given below the Lists:

<table>
<thead>
<tr>
<th>List I (Refrigerant)</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Refrigerant 11</td>
<td>1. CC₁₂F₂</td>
</tr>
<tr>
<td>B. Refrigerant 12</td>
<td>2. C₂Cl₂F₄</td>
</tr>
<tr>
<td>C. Refrigerant 22</td>
<td>3. CCl₃F</td>
</tr>
<tr>
<td>D. Refrigerant 114</td>
<td>4. CHClF₂</td>
</tr>
<tr>
<td></td>
<td>5. CH₂ClF</td>
</tr>
</tbody>
</table>

Codes: A  B  C  D   A  B  C  D
(a) 2  1  5  3   (b) 3  4  5  2
(c) 3  1  4  2   (d) 5  1  4  3

12. Ans. (c) 

13. The refrigerant - 12 (\(R - 12\)) used in vapour compression refrigeration system is
\(R(C - 1)(H + 1)F\) therefore \(C = 1, H = 0, F = 2, Cl = 2\)

14. Match List I with List II and select the correct answer using the codes given below the lists:

<table>
<thead>
<tr>
<th>List I (Refrigerant)</th>
<th>List II (Designation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Dichlorodifluoromethane</td>
<td>1. R 718</td>
</tr>
<tr>
<td>B. Water</td>
<td>2. R 22</td>
</tr>
<tr>
<td>C. Methyl chloride</td>
<td>3. R40</td>
</tr>
<tr>
<td>D. Monochloride-fluoromethane</td>
<td>4. R 12</td>
</tr>
</tbody>
</table>

Codes: A  B  C  D   A  B  C  D
(a) 4  1  2  3   (b) 1  4  3  2
(c) 1  4  2  3   (d) 4  1  3  2

14. Ans. (d)
Secondary Refrigerants

15. Consider the following statements: [IES-1996]
   1. Practically all common refrigerants have approximately the same COP and power requirement.
   2. Ammonia mixes freely with lubricating oil and this helps lubrication of compressors.
   3. Dielectric strength of refrigerants is an important property in hermetically sealed compressor units.
   4. Leakage of ammonia can be detected by halide torch method.
   Of these statements (a) 1, 2 and 4 are correct (b) 2 and 4 are correct (c) 1, 3 and 4 are correct (d) 1 and 3 are correct
   15. Ans. (d) Practically all refrigerants, except CO₂ have fairly same COP and power requirements. Thus statement (a) is correct.
   Ammonia does not mix freely with lubricating oil. Therefore statement (b) is wrong.
   Dielectric strength of refrigerants is an important property in hermetically sealed compressor units.
   Leakage of ammonia is detected by its odour or sulphur candle with which ammonia forms white smoke like fumes. Thus statements 1 and 4 are correct and choice (d) is the right choice.

16. In milk chilling plants, the usual secondary refrigerant is [IES-1998]
   (a) ammonia solution (b) sodium silicate (c) glycol (d) brine
   16. Ans. (c)

17. Assertion (A): Freon-12 is odourless and its leakage cannot be easily detected. However, it is preferred in comfort air-conditioning. [IAS 1994]
   Reason (R): It is almost impossible for Freon-12 leakage to attain a fatal concentration.
   17. Ans. (a)

18. The leakage in a Freon-based refrigeration system can be detected by using a/an [IES-2000]
   (a) oxy-acetylene torch (b) halide torch (c) sulphur torch (d) blue litmus paper
   18. Ans. (b)

19. Match List I with List II and select the correct answer [IES-1994]

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Freon 12</td>
<td>1. Centrifugal systems</td>
</tr>
<tr>
<td>B. Freon 22</td>
<td>2. Low temperature cold storage</td>
</tr>
<tr>
<td>C. Freon 11</td>
<td>3. Window type a/c units</td>
</tr>
<tr>
<td>D. Ammonia</td>
<td>4. Ice plants</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Codes:</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>(b) 3</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>(c)</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>(d) 1</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

19. Ans. (a)
20. The pipes and fitting in an ammonia refrigeration system should be made of
(a) cast steel or wrought iron  (b) aluminium  (c) naval brass  (d) copper  [IAS-1998]
20. Ans. (a)

Substitutes for CFC Refrigerants

Azeotropic Mixtures

21. Match List-I with List-II and select the correct answer using the codes given below
the lists:  [IAS-2004]

<table>
<thead>
<tr>
<th>List-I</th>
<th>List-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Sulphur candle test</td>
<td>1. Propane</td>
</tr>
<tr>
<td>B. Halide torch test</td>
<td>2. Ammonia</td>
</tr>
<tr>
<td>C. Soap and water test</td>
<td>3. Halocarbon refrigerants</td>
</tr>
<tr>
<td>D. Ammonia swab test</td>
<td>4. Sulphur dioxide</td>
</tr>
</tbody>
</table>

Codes: A  B  C  D  A  B  C  D
(a) 2  3  1  4  (b) 4  1  3  2
(c) 2  1  3  4  (d) 4  3  1  2
21. Ans. (a)

22. Consider the following statements:  [IAS-1999]
1. In Freon 22 system, moisture chocking generally does not occur.
2. Freon 11 is mainly used in large capacity air-conditioning plants with centrifugal
compressor.
3. Pressure of lubricating oil in evaporator will increase the heat transfer coefficient.
4. Refrigerants that are completely miscible with oil, do not cause oil chocking.
Of these statements:
(a) 1, 2 and 3 are correct  (b) 1, 2 and 3 correct
(c) 2, 3 and 4 correct  (d) 1, 3 and 4 are correct
22. Ans. (b)

23. Which one of the following refrigerants has the highest critical temperature?
(a) Water  (b) Carbon dioxide  (c) Freon 12  (d) Ammonia  [IAS-1996]
23. Ans. (a)

24. The significant advantage of using ammonia as a refrigerant is its  [IAS-1996]
(a) characteristic odour  (b) high latent heat  (c) solubility  (d) inflammability
24. Ans. (b)

25. The use of Refrigerant - 22 (R-22) for temperatures below - 30°C is not
recommended due to its  [GATE-1993]
(a) good miscibility with lubricating oil  (b) poor miscibility with lubricating oil
(c) low evaporating pressure  (d) high compressor discharge temperature
25. Ans. (d)

26. Selection of a refrigerant for a vapour – compression system depends on which
among the following?  [IES 2007]
(a) Toxicity  (b) Environmental effect
(c) Saturation pressure – temperature relationship  (d) All of the above
26. Ans. (d)
27. Which one of the following is the fluid whose properties in all its three phase are made use of in thermodynamics?
   (a) Ammonia    (b) Freon 12
   (c) Helium    (d) Water

27. Ans. (d)

28. Oil separator is NOT required in refrigeration system if
   (a) refrigerant and oil are immiscible at all pressures and temperatures
   (b) refrigerant and oil are immiscible at condensation pressure and temperature
   (c) refrigerant and oil are miscible at all pressures and temperatures
   (d) refrigerant and oil are miscible at condensation pressures and temperature.

28. Ans. (c)

29. Ozone depletion by CFCs occurs by breakdown of
   (a) chlorine atoms from refrigerant by UV radiation and reaction with ozone in troposphere
   (b) fluorine atoms from refrigerant by UV radiation and reaction with ozone in troposphere
   (c) chlorine atoms from refrigerant by UV radiation and reaction with ozone in stratosphere
   (d) fluorine atoms from refrigerant by UV radiation and reaction with ozone in stratosphere

29. Ans. (c)

30. Consider the following statements:
    In ammonia refrigeration systems, oil separator is provided because
    1. Oil separation in evaporator would lead to reduction in heat transfer coefficient.
    2. Oil accumulation in the evaporator causes choking of evaporator.
    3. Oil is partially miscible in the refrigerant.
    4. Oil causes choking of expansion device.

   Of these statements
   (a) 1 and 2 are correct      (b) 2 and 4 are correct
   (c) 2, 3 and 4 are correct   (d) 1, 3 and 4 are correct

30. Ans. (b)

31. Consider the following statements:
    Moisture should be removed from refrigerants to avoid
    1. compressor seal failure.   2. freezing at the expansion valve.
    3. restriction to refrigerant flow.  4. corrosion of steel parts.

   Of these statements
   (a) 1, 2, 3 and 4 are correct  (b) 1 and 2 are correct
   (c) 2, 3 and 4 are correct      (d) 1, 3 and 4 are correct.

31. Ans. (a) All the statements about effect of moisture on refrigerant are correct.

32. The color of the flame of halide torch, in a case of leakage of Freon refrigerant, will change to
   (a) bright green  (b) yellow  (c) red    (d) orange

32. Ans. (a)

33. The leaks in a refrigeration system Freon are detected by:
(a) A halide torch, which on detecting produces greenish flame light
(b) Sulphur sticks, which on detecting give white smoke
(c) Using reagents
(d) Sensing reduction in pressures

33. Ans. (a)

34. Ideal refrigeration mixture is one which
(a) Obeys Raoult's law in liquid phase and does not obey Dalton's law in vapour phase
(b) Does not obey Raoult's law in liquid phase and does not obey Dalton's law in vapour phase
(c) Obeys Raoult's law in liquid phase and obeys Dalton's law in vapour phase
(d) Does not obey Raoult's law in liquid phase and obeys Dalton's law in vapour phase

34. Ans. (c)
Answers with Explanation (Objective)
4. Refrigerant Compressors

Highlight

For gas compressor [always use Reversible process]

a. Work required for Reversible polytropic compression

\[ W = \frac{n}{n-1} P_1 V_1 \left( \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right) \]  
(all n)

b. Work required for Reversible Adiabatic compression

\[ W = \frac{\gamma}{\gamma-1} P_1 V_1 \left( \left( \frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right) \]  
(all \( \gamma \))

c. But Work required when polytropic as well as adiabatic compression

\[ W = \frac{\gamma}{\gamma-1} P_1 V_1 \left( \left( \frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right) \]  
(mix of n and \( \gamma \))

[Note: In reversible polytropic there is heat transfer but in this case, adiabatic, heat transfer is not there.]
Objective Questions (IES, IAS, GATE)

Types of Compressors

1. Match List I with II and select the correct answer using the code given below the Lists:

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Name of Equipment)</td>
<td>(Pressure Ratio)</td>
</tr>
<tr>
<td>A. Fan</td>
<td>1. 1.1</td>
</tr>
<tr>
<td>B. Blower</td>
<td>2. 2.5</td>
</tr>
<tr>
<td>C. Centrifugal air compressor</td>
<td>3. 4</td>
</tr>
<tr>
<td>D. Axial flow air compressor</td>
<td>4. 10</td>
</tr>
</tbody>
</table>

Code:

- A B C D   A B C D
- (a) 2 1 3 4
- (b) 1 2 3 4
- (c) 1 2 4 3
- (d) 2 1 4 3

1. Ans. (b)

2. Which of the following can be the cause/causes of an air-cooled compressor getting overheated during operation?
   1. Insufficient lubricating oil.
   2. Broken valve strip.
   3. Clogged intake filter.

Select the correct answer using the code given below:

- (a) Only 3
- (b) Only 1 and 2
- (c) Only 2 and 3
- (d) 1, 2 and 3

2. Ans. (d)

3. Which type of valves is generally used in reciprocating refrigerant compressors?

- (a) Mushroom valve
- (b) Puppet valve
- (c) Plate valve
- (d) Throttle valve

3. Ans. (c)

4. Which one of the following statements is correct?

In reciprocating compressors, one should aim at compressing the air

- (a) adiabatically
- (b) isentropically
- (c) isothermally
- (d) polytropically

4. Ans. (c)

5. Roots blower is an example of

- (a) Reciprocating (positive displacement) compressor
- (b) Rotary (positive displacement) compressor
- (c) Centrifugal compressor
- (d) Axial compressor

5. Ans. (b)

6. Match List I with List II and select the correct answer:

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
</table>

- (a) 2 1 3 4
- (b) 1 2 3 4
- (c) 1 2 4 3
- (d) 2 1 4 3

1. Ans. (b)
(Refrigeration equipment) (Characteristic)
A. Hermetically sealed compressor 1. Capillary tube
B. Semi-hermitically sealed compressor 2. Both compressor and motor enclosed in a shell or casing
C. Open type compressor 3. Both compressor and motor enclosed in a shell or casing with a removable cylinder cover
D. Expansion device 4. Driving motor of enclosed in a shell or casing and connected to the shaft driving the compressor

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>(b)</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>(c)</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>(d)</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

6. Ans. (b)

7. The capacity of an air compressor is specified as 10 m³/min. It means that the compressor is capable of [IES-2000]
   (a) supplying 3 m³ of compressed air per minute
   (b) compressing 3 m³ of free air per minute
   (c) supplying 3 m³ of compressed air at NTP
   (d) compressing 3 m³ of standard air per minute
   7. Ans. (a)

8. Which one of the following pairs of features and compressors type is NOT correctly matched? [IES-2000]
   (a) Intake and delivery ports compression is attained by: Vane compressor back flow and internal compression cylindrical rotor set to eccentric casing
   (b) Intermittent discharge requires receiver, produces high : Reciprocating compressor pressure, slow speed and lubrication problems
   (c) Continuous flow, radial now, handles large volume : Centrifugal compressor much higher speed and fitted into design of aero-engine
   (d) Successive pressure drops through contracting : Axial flow compressor passages, blades are formed from a number of circular arcs, axial now
   8. Ans. (c)

9. When a burnt out hermetic compressor is replaced by a new one, it is desirable to include in the system a large drier-cum-strainer also. This is to be placed in [IES-1999]
   (a) liquid line  (b) suction line  (c) hot gas line  (d) discharge line
   9. Ans. (d)

10. Assertion (A): A reciprocating air compressor at sea level would deliver a greater mass of air than a compressor on a mountain. [IES-1998]
    Reason (R): The compressor ratings are given for “free air”.
    10. Ans. (b)

11. What is the preferred intercooler pressure for a two stage air compressor working between the suction pressure p_s and the delivery pressure P_d? [IES-2006]
    (a) (p_s + p_d)/2  (b) (p_s + p_d)/2  (c) (p_s + p_d)^{1/2}  (d) (p_s + p_d)^{1/4}
    11. Ans. (c)

12. When are shock waves formed in air compressors? [IES-2006]
12. Ans. (b)

13. Assertion (A): In multi-stage compressors, the polytropic efficiency is always greater than the isentropic efficiency. [IES-2005]
   Reason (R): Higher the pressure ratio, the greater is the polytropic efficiency.
   Ans. (b)

14. For a two-stage reciprocating air compressor, the suction pressure is 1.5 bar and the delivery pressure is 54 bar. What is the value of the ideal intercooler pressure?
   (a) 6 bar  (b) 9 bar  (c) 27.75 bar  (d) 9/\(\sqrt{2}\) bar [IES-2004]
   Ans. (b) \(P_i = \sqrt{P_1 P_2} = \sqrt{54 \times 1.5} = 9\) bar

15. During steady flow compression process of a gas with mass flow rate of 2 kg/s.
   increase in specific enthalpy is 15 kJ/kg and decrease in kinetic energy is 2 kJ/kg. The rate of heat rejection to the environment is 3 kW. The power needed to drive the compressor is
   (a) 23 kW  (b) 26 kW  (c) 29 kW  (d) 37 kW [IES-2003]
   Ans. (c) Power needed to drive the compression

   Using, S.F.E.E., we get:
   \[ h_1 + \frac{v_1^2}{2} + Q = h_2 + \frac{v_2^2}{2} + W \]
   \[ W = -3 - 30 + 4 = -29\) kW

16. In a two-stage compressor with ideal intercooling, for the work requirement to be minimum, the intermediate pressure \(P_i\) in terms of condenser and evaporator pressure \(P_c\) and \(p_e\) respectively is [IES-2003]
   (a) \(P_i = P_c P_e\)  (b) \(P_i = \sqrt{P_c P_e}\)  (c) \(P_i = \sqrt{P_c / P_e}\)  (d) \(P_i = P_c / P_e\)
   Ans. (b)

17. When a refrigerator system is started from ambient conditions, the evaporator temperature decreases from ambient temperature to design value. This period is known as a pull-down period. The power requirement of compressor during pull-down
   (a) decreases continuously  (b) increases continuously [IES-2003]
   (c) remains constant  (d) increases and then decreases
   Ans. (b)

18. If \(n\) is the polytropic index of compression and \(\frac{P_2}{P_1}\) is the pressure ratio for a three-stage compressor with ideal intercooling, the expression for the total work of three stage is [IES-2001]
   \[ \frac{3n}{n-1} P_1 v_1 \left( \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right) \]  (a)
   \[ \frac{n}{n-1} P_1 v_1 \left( \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{3n}} - 1 \right) \]  (b)
\[ \frac{n}{(n-1)} p_1 v_1 \left( \frac{p_2}{p_1} \right)^{(n-1)/n} - 1 \]  
\[ \frac{3n}{(n-1)} p_1 v_1 \left( \frac{p_2}{p_1} \right)^{3a} - 1 \]

18. Ans. (d)

19. The air with enthalpy of 100kJ/kg is compressed by an air compressor to a pressure and temperature at which its enthalpy becomes 200kJ/kg. The loss of heat is 40kJ/kg from the compressor as the air passes through it. Neglecting kinetic and potential energies, the power required for an air mass flow of 0.5kg/s is [IES-2000]
(a) 30kW  
(b) 50kW  
(c) 70 kW  
(d) 90 kW
19. Ans. (a)

20. A two-stage compressor takes in air at 1.1 bar and discharges at 20 bar. For maximum efficiency, the intermediate pressure is [IES-2000]
(a) 10.55 bars  
(b) 7.33 bars  
(c) 5.5 bar  
(d) 4.7 bar
20. Ans. (d)

21. The discharge pressure of the compressor in the refrigeration system goes up due to the
(a) lower volumetric efficiency of the compressor  
(b) formation of scale in the condenser  
(c) large size of the condenser  
(d) undercharge of the refrigerant  [IES-2000]
21. Ans. (b)

22. A 3-stage reciprocating compressor has suction pressure of 1 bar and delivery pressure of 27 bar. For minimum work of compression, the delivery pressure of 1st stage is [IES-1999]
(a) 14 bar  
(b) 9 bar  
(c) 5.196 bar  
(d) 3bar
22. Ans. (d) For minimum work of compression in 3 stage compressor the delivery pressure of 1st stage is \( \sqrt{27/1} = 3 \) bar = 3 bar

23. Which one of the following statements is true? [IES-1998]
(a) In a multi-stage compressor, adiabatic efficiency is less than stage efficiency  
(b) In a multi-stage turbine, adiabatic efficiency is less than the stage efficiency  
(c) Preheat factor for a multi-stage compressor is greater than one  
(d) Preheat factor does not affect the multi-stage compressor performance
23. Ans. (c)
24. The heat rejection by a reciprocating air compressor during the reversible compression process AB, shown in the following temperature-entropy diagram, is represented by the area:
(a) ABC    (b) ABDE    (c) ABFG    (d) ABFOE

24. Ans. (b) Heat rejection during AB is given by area below it on entropy axis, i.e. ABDE. DES

25. For a multistage compressor, the polytropic efficiency is
(a) the efficiency of all stages combined together    (b) the efficiency of one stage.
(c) constant throughout for all the stages    (d) a direct consequence of the pressure ratio.

25. Ans. (a) For multistage compressor, the polytropic efficiency is the efficiency of all stages combined together

26. Phenomenon of choking in compressor means
(a) no flow of air.
(b) fixed mass flow rate regardless of pressure ratio.
(c) reducing mass flow rate with increase in pressure ratio.
(d) increased inclination of chord with air stream.

26. Ans. (b) Phenomenon of choking in compressor means fixed mass flow rate regardless of pressure ratio

27. The usual assumption in elementary compressor cascade theory is that
(a) axial velocity through the cascade changes.
(b) for elementary compressor cascade theory, the pressure rise across the cascade is given by equation of state.
(c) axial velocity through the cascade does not change.
(d) with no change in axial velocity between inlet and outlet, the velocity diagram is formed.

27. Ans. (c) The usual assumption in elementary compressor cascade theory is that axial velocity through the cascade does not change.

28. In a reciprocating air compressor the compression works per kg of air
(a) increases as clearance volume increases.
(b) decreases as clearance volume increases.
(c) is independent of clearance volume.
(d) increases with clearance volume only for multistage compressor.

28. Ans. (a) Compression work per kg of air increases as clearance volume increases.

29. Assertion (A): The isothermal efficiency of a reciprocating compressor becomes 100% if perfect cooling of the fluid during compression is attained.
Reason (R): Work done in a reciprocating compressor is less if the process of compression is isothermal rather than polytropic.

29. Ans. (a) Both assertion and reason are correct and R provides correct explanation for A.

30. Consider the following statements:

1. Reciprocating compressors are best suited for high pressure and low volume capacity.
2. The effect of clearance volume on power consumption is negligible for the same volume of discharge.
3. While the compressor is idling, the delivery valve is kept open by the control circuit.
4. Inter-cooling of air between the stages of compression helps to minimize losses.

Of these statements

(a) 1 and 2 are correct
(b) 1 and 3 are correct
(c) 2 and 4 are correct
(d) 3 alone is correct

30. Ans. (b)

31. The inlet and exit velocity diagrams of a turbomachine rotor are shown in the given figure. The turbomachine is

(a) an axial compressor with backward curved blades
(b) a radial compressor with backward curved blades
(c) a radial compressor with forward curved blades
(d) an axial compressor with forward curved blades

31. Ans. (c) From inlet and outlet diagrams it will be seen the blade velocity $u_2 > u_1$ from which it is clear that it is radial compressor. For axial compressor, $u_2 = u_1$. Further in outlet velocity triangle, velocity $V_{r_2}$ is in the direction of $u_2$ which means blades are forward curved. In case of backward curved blades the direction of $V_{r_2}$ will be opposite to that of $u_2$ i.e. angle between $V_{r_2}$ & $u_2$ will be acute.

32. For two stage compressor in which index of compression for low pressure stage is $m$ and for high pressure stage in $n$. The load shearing with perfect inter-cooling is expressed as:

(a) $\frac{W_1}{W_2} = \frac{m(n-1)}{n(m-1)}$
(b) $\frac{W_1}{W_2} = \frac{n(n-1)}{m(m-1)}$
(c) $\frac{W_1}{W_2} = \frac{n}{m}$
(d) $\frac{W_1}{W_2} = \frac{m}{n}$

32. Ans. (a)

33. p-v diagram has been obtained from a test on a reciprocating compressor. Which of the following represents that diagram?

[GATE-2005]
33. Ans. (d) It is obtained from a test, so $p_{out}$ will be some less than compressor outlet pressure for opening the delivery valve.

34. A single-acting two-stage compressor with complete intercooling delivers air at 16 bar. Assuming an intake state of 1 bar at 15°C, the pressure ratio per stage is
   (a) 16   (b) 8   (c) 4   (d) 2  \[\text{GATE-2001}\]
   34. Ans. (c) Pressure ratio of each stage must be same
   \[
   r_p = \frac{p_2}{p_1} = \sqrt{\frac{p_1 	imes p_2}{p_1 	imes p_1}} = \sqrt{16} = 4
   \]

35. Air ($C_p = 1 \text{ kJ/kg, } \gamma = 1.4$) enters a compressor at a temperature of 27°C. The compressor pressure ratio is 4. Assuming an efficiency of 80%, the compressor work required in kJ/kg is
   (a) 160   (b) 172   (c) 182   (d) 225 \[\text{GATE-1998}\]
   35. Ans. (c) $W_{\text{ideal}} = \frac{RT_1}{\gamma - 1} \left[ \left( \frac{p_2}{p_1} \right)^{\gamma - 1} - 1 \right] = c_p T_1 \left[ \left( \frac{p_2}{p_1} \right)^{\gamma - 1} - 1 \right] = 1 \times 300 \left[ 4^{1.4} - 1 \right] = 146 \text{ kJ/kg}$
   $W_{\text{actual}} = \frac{W_{\text{ideal}}}{\eta} = \frac{146}{0.8} = 182 \text{ kJ/kg}$

36. Consider a two-stage reciprocating air compressor with a perfect intercooler operating at the best intermediate pressure. Air enters the low pressure cylinder at 1 bar, 27°C and leaves the high pressure cylinder at 9 bar. Assume the index of compression and expansion in each stage is 1.4 and that for air $R = 286.7 \text{ J/kg K}$, the work done per kg air in the high pressure cylinder is
   (a) 111 kJ   (b) 222 kJ   (c) 37 kJ   (d) 74 kJ \[\text{GATE-1997}\]
   36. Ans. (a)
Pressure ratio must be same

\[ \therefore r_p = \frac{P_2}{P_1} = \frac{P_1 \times P_2}{P_1} = \frac{P_1}{P_1} = \frac{9}{1} = 3 \]

Work done of each stage also same

\[ W_{\text{each stage}} = \frac{\gamma RT}{\gamma - 1} \left[ \frac{\gamma - 1}{\gamma} \right] = \frac{1.4 \times 287 \times 300}{(1.4 - 1)} \left[ \frac{\frac{1.4 - 1}{1.4} - 1}{1} \right] = 111 \text{ kJ} \]

37. For an air-conditioning plant above 300 ton, which one of the following systems would normally be preferred?
   (a) Ammonia reciprocating compressor (b) Centrifugal chiller (c) Absorption refrigeration system (d) Hermetic compressor

   37. Ans. (a) Ammonia reciprocating compressor is preferred

38. When the discharge pressure is too high in a refrigeration system, high pressure control is installed to
   (a) stop the cooling fan  (b) stop the water circulating pump  (c) regulate the flow of cooling water  (d) stop the compressor.

   38. Ans. (c) When the discharge pressure is too high in refrigeration system, high pressure control is installed to regulate the flow of cooling water

39. What is the cause of burn out of hermetically sealed refrigerant compressors?
   (a) Phase to phase short because of worn insulation  (b) By prolonged overload operation  (c) By some mechanical failure  (d) All the above

   39. Ans. (d)

40. Which of the following are the special features of a hermetically sealed compressor of a refrigerator?

   1. The compressor may be reciprocating to rotary type
   2. No shaft seal is necessary
   3. More silent in operation
   4. COP is more than that of open compressor

   Select the correct answer using the codes given below:
   (a) 2 and 4  (b) 1, 2 and 3  (c) 1, 3 and 4  (d) 2, 3 and 4

   40. Ans. (b)

41. Use of hermetically sealed compressor in a vapour compression refrigeration system results in
   (a) decrease in energy consumption  (b) increase in energy consumption  (c) increase in COP  (d) increase in pressure ratio

   41. Ans. (a)

42. When does L.P. cut-off occur in a refrigeration system?
   (a) If the ambient temperature is low  (b) If non-condensable gases are present in the condenser  (c) If refrigerant charge is low  (d) If lubricating oil gets accumulated in the condenser

   42. Ans. (a)
43. A refrigeration compressor designed to operate with R 22………. (can/cannot) be operated with R 12 because the condensing pressure of R22 at any given temperature is……..(higher/lower) than that of R 12. [GATE-1992]

43. Ans. cannot; higher

44. Select statements from List II matching the processes in List I. Enter your answer as A, B if the correct choice for (1) is (A) and that for (2) is (B) [GATE-1999]

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Inter-cooling</td>
<td>(A) No heat transfer during compression</td>
</tr>
<tr>
<td>(2) Isothermal compression</td>
<td>(B) Reduces low pressure compressor work</td>
</tr>
<tr>
<td></td>
<td>(C) Heat rejection during compression</td>
</tr>
<tr>
<td></td>
<td>(D) Reduces high pressure compressor work</td>
</tr>
</tbody>
</table>

44. Ans. (c, d)

45. The optimum intermediate pressure $P_i$ for a gas turbine plant operating between pressure limits $P_1$ and $P_2$ with perfect inter cooling between the two stages of compression (with identical isentropic efficiency is given by [IES-2003,IES-1996]

(a) $P_i = P_2 - P_1$  
(b) $P_i = \frac{1}{2} (P_1 + P_2)$  
(c) $P_i = \sqrt{\frac{P_1}{P_2}}$  
(d) $P_i = \sqrt{\frac{P_2^2}{P_1^2} - P_i^2}$

45. Ans. (c): We know that for minimum compressor work pressure ratio of both stage must be same so $\frac{P_i}{P_1} = \frac{P_i}{P_2}$ or $P_i = \sqrt{\frac{P_1}{P_2}}$

46. For a two stage-reciprocating compressor, compression from $P_1$ to $P_2$ is with perfect inter-cooling and no Pressure losses. If compression in both cylinders follows the same poly-tropic process and the atmospheric pressure is $P_a$, then the intermediate pressure $P_i$ is given by [IES-1994]

(a) $P_i = P_2 - P_1$  
(b) $P_i = \frac{1}{2} (P_1 + P_2)$  
(c) $P_i = \sqrt{\frac{P_1}{P_2}}$  
(d) $P_i = \sqrt{\frac{P_2^2}{P_1^2} - P_i^2}$

46. Ans. (c): We know that for minimum compressor work pressure ratio of both stages must be same so $\frac{P_i}{P_1} = \frac{P_i}{P_2}$ or $P_i = \sqrt{\frac{P_1}{P_2}}$ Note: Here $P_a$ is superfluous data that has no use.

47. Two-stage compressors takes in air at 1.1 bar and discharges at 20 bar. For maximum efficiency, the intermediate pressure is [IES-2000]

(a) 10.55 bar  
(b) 7.33 bar  
(c) 5.5 bar  
(d) 4.7 bar

47. Ans. (d): We know that for minimum compressor work pressure ratio of both stages must
be same so \( \frac{P_1}{P_i} = \frac{P_i}{P_2} \) or \( P_i = \sqrt[3]{\frac{P_1}{P_2}} = \sqrt[3]{1.1} \times 20 = \sqrt[3]{22} = 4.7 \text{ bar} \)

48. 3-stage reciprocating compressors have suction pressure of 1 bar and delivery pressure of 27 bar. For minimum work of compression, the delivery pressure of first stage is
(a) 14 bar  (b) 9 bar  (c) 5.196 bar  (d) 3 bar  \text{ [IES-1999]}
48. Ans. (d): We know that for minimum compressor work pressure ratio of 3-stage must be same so 
\[
\frac{P_i}{P_1} = \frac{P_2}{P_i} = \frac{P_3}{P_2} = \frac{P_4}{P_3} = \frac{P_5}{P_4} = \frac{P_6}{P_5} = 3 \]

or \( P_i = P_1x \frac{3}{3} P_i = P_1 \frac{2}{3} \) \( P_2 = 1 \times 27 \frac{1}{3} = 3 \text{ bar} \)

49. In a gas turbine cycle with two stages of reheating, working between maximum pressure \( P_1 \) and minimum pressure \( P_4 \), the optimum pressures would be
(a) \( (P_1 P_4)^{1/3} \) and \( (P_1 P_4)^{2/3} \)  (b) \( (P_1^2 P_4)^{1/3} \) and \( (P_1 P_4)^{1/3} \)
(c) \( (P_1 P_4)^{1/2} \) and \( P_1 P_4^{2/3} \)  (d) \( (P_1 P_4)^{1/2} \) and \( (P_1 P_4)^{2/3} \)  \text{ [IES-1993]}
49. Ans. (b) We know that for minimum compressor work pressure ratio of 3-stage must be same so 
\[
\frac{P_2}{P_1} = \frac{P_3}{P_2} = \frac{P_4}{P_3} = \frac{P_5}{P_4} = \frac{P_6}{P_5} = 3 \]

or \( P_2 = P_1 \times \frac{3}{3} P_i = (P_1^2 P_4)^{1/3} \) and \( P_3 = \frac{P_4}{P_3} = (P_1 P_4)^{2/3} \)

Alternatively you may give answer by dimensional similarity. Only choice (b) has the dimension of pressure.

50. Four-stage compressor with perfect inter-cooling between stages compresses air from 1 bar to 16 bar. The optimum pressure in the last intercooler will be
(a) 6 bar  (b) 8 bar  (c) 10 bar  (d) 12 bar  \text{ [IES-1998]}
50. Ans. (b): We know that for minimum compressor work pressure ratio of 4-stage must be same so 
\[
\frac{P_2}{P_1} = \frac{P_3}{P_2} = \frac{P_4}{P_3} = \frac{P_5}{P_4} = \frac{P_6}{P_5} = 4 \]

or \( P_3 = P_1 \times \frac{4}{4} P_2^{\frac{1}{4}} P_2^{\frac{2}{4}} = 1^{1/4}x(16)^{1/4} = 8 \text{ bar} \)
Volumetric Efficiency of reciprocating Compressors

51. Which one of the following statements is correct for reciprocating air compressor?
(a) Its volumetric efficiency increases with increasing clearance ratio
(b) Its volumetric efficiency increases with increasing pressure ratio
(c) Its volumetric efficiency does not vary with change in clearance ratio and pressure ratio
(d) Its volumetric efficiency decreases with increasing clearance ratio and pressure ratio,
both

[IES 2007]

51. Ans. (d) \[ \eta_v = 1 + C - C \left( \frac{p_2}{p_1} \right)^{\frac{1}{n}} \]

52. Consider the following statements:
Volumetric efficiency of a reciprocating air compressor increases with
1. increase in clearance ratio
2. decrease in delivery pressure
3. multi staging
Which of the statements given above is/are correct?
(a) Only 1 and 2   (b) Only 2 and 3  (c) Only 3  (d) 1, 2 and 3

[IES-2006]

52. Ans. (b) \[ \eta_v = 1 + C - C \left( \frac{p_2}{p_1} \right)^{\frac{1}{n}} \text{ if } p_2 \downarrow \text{ then } \eta_v \uparrow \]

53. The clearance volume of a reciprocating compressor directly affects
(a) piston speed    (b) noise level
(c) volumetric efficiency  (d) temperature of air after compression

[IAS-1998]

53. Ans. (c) \[ \eta_v = 1 + c - c \left( \frac{p_2}{p_1} \right)^{\frac{1}{n}} \]

54. Which of the following statements are correct for multi staging in a reciprocating air compressor?
1. It decreases the volumetric efficiency.
2. The work done can be reduced.
3. A small high-pressure cylinder is required.
4. The size of flywheel is reduced.
Select the correct answer using the codes given below
(a) 1, 2 and 3   (b) 2, 3 and 4  (c) 1, 3 and 4  (d) 1, 2 and 4

[IES-2006]

54. Ans. (b) 1 is false, It increases the volumetric efficiency.

55. Consider the following statements
The volumetric efficiency of a reciprocating compressor can be enhanced by
1. heating the intake air   2. decreasing the clearance volume
3. cooling the intake air
Which of these statements is/are correct?
(a) 1 alone   (b) 1 and 2   (c) 2 and 3   (d) 3 alone

[IES-2000]

55. Ans. (c)
56. Assertion (A): Decrease of pressure and increase of temperature of the refrigerant in the suction pipeline connecting the evaporator to the reciprocating compressor reduces the refrigerating capacity of the system. [IES-2003]
Reason (R): Decrease of pressure and increase of temperature of the refrigerant in the suction pipeline connecting the evaporator to the compressor reduces the volumetric efficiency of the reciprocating compressor.  
56. Ans. (a)

57. The ratio of the clearance volume to the displacement volume of a R12 reciprocating compressor is 0.05. Specific volume at inlet and outlet of compressor are 0.04 and 0.02 m³/kg respectively. Volumetric efficiency of the compressor is [IES-2002]
(a) 95.0% (b) 47.5% (c) 38.0% (d) 19.0%  
57. Ans. (a)

58. Consider the following statements: [IES-1996]
The volumetric efficiency of a compressor depends upon  
1. clearance volume  
2. pressure ratio  
3. index of expansion.  
Of these correct statements are  
(a) 1 and 2 (b) 1 and 3 (c) 2 and 3 (d) 1, 2, and 3  
58. Ans. (d) The volumetric efficiency of a compressor depends upon 1. clearance volume 2. pressure ratio 3. index of expansion.

59. A gas engine has a swept volume of 300 cc and clearance volume of 25 cc. Its volumetric efficiency is 0.88 and mechanical efficiency is 0.90. What is the volume of the mixture taken in per stroke?  
IES-1995]
(a) 248 cc (b) 252 cc (c) 264 cc (d) 286 cc  
59. Ans. (c) Volumetric efficiency $\eta = \frac{\text{Volume of mixture}}{300}$, and volume of mixture = 300 x 0.88 = 264 cc

60. Which of the following statements does NOT apply to the volumetric efficiency of a reciprocating air compressor?  
[GATE-1999]
(a) It decreases with increase in inlet temperature  
(b) It increases with decrease in pressure ratio  
(c) It increases with decrease in clearance ratio  
(d) It decreases with increase in clearance to stroke ratio  
60. Ans. (a)

61. Which of the following are the reasons for the volumetric efficiency of reciprocating compressor being less than 100%?  
[IAS-1995]
1. Deviations from isentropic process.  
2. Pressure drop across the valves.  
3. Superheating in compressor.  
5. Deviations from isothermal process  
6. leakages.  
Select the correct answer from the codes given below:  
(a) 1, 2, 3 and 5 (b) 2, 3, 4 and 5 (c) 1, 4, 5 and 6 (d) 2, 3 and 6  
61. Ans. (d) The reason for volumetric efficiency of reciprocating compressor being less than 100% are pressure drop across the valves, superheating in compressor, clearance volume and leakages.
**Effect of Clearance on Work**

62. Consider the following statements:  

In a reciprocating compressor, clearance volume is provided.  
1. so that piston does not hit and damage the valves  
2. to account for differential thermal expansion of piston and cylinder  
3. to account for machining tolerances  
4. to achieve isentropic compression  

Which of these statements are correct?  
(a) 1, 2 and 3  
(b) 1, 2 and 4  
(c) 1, 3 and 4  
(d) 2, 3 and 4  

62. Ans. (a) In centrifugal compressor there also isentropic compression occurs so.

63. A large clearance volume in a reciprocating compressor results in  
(a) reduced volume flow rate  
(b) increased volume flow rate  
(c) lower suction pressure  
(d) lower delivery pressure.  

63. Ans. (d) Large clearance volume in reciprocating compressor results in lower delivery pressure.

64. Clearance volume of a reciprocating compressor is 100 ml, and the volume of the cylinder at bottom dead centre is 1.0 litre. The clearance ratio of the compressor is  
(a) $\frac{1}{11}$  
(b) $\frac{1}{10}$  
(c) $\frac{1}{9}$  
(d) $\frac{1}{12}$  

64. Ans. (c) Piston displacement volume = 900 ml  
   Therefore clearance ratio = $\frac{\text{clearance volume}}{\text{Piston displacement volume}} = \frac{100}{900} = \frac{1}{9}$

65. A R-12 refrigerant reciprocating compressor operates between the condensing temperature of 30°C and evaporator temperature of −20°C. The clearance volume ratio of the compressor is 0.03. Specific heat ratio of the vapour is 1.15 and the specific volume at the suction is 0.1089 m³/kg. Other properties at various states are given in the figure. To realize 2 Tons of refrigeration, the actual volume displacement rate considering the effect of clearance is  
(a) $6.35 \times 10^{-3}$ m³/s  
(b) $63.5 \times 10^{-3}$ m³/s  
(c) $635 \times 10^{-3}$ m³/s  
(d) $4.88 \times 10^{-3}$ m³/s  

65. Ans. (a)
Performance Characteristics of Reciprocating Compressors

66. Which of the following techniques are employed for control of reciprocating compressors?
   1. Throttle control  2. Clearance control  3. Blowing air to waste

Select the correct answer using the code given below:

(a) 1, 2 and 3        (b) 1 and 2 only        (c) 2 and 3 only        (d) 1 and 3 only

66. Ans. (d)

67. Reciprocating compressors are provided with
   (a) simple disc/plate valve      (b) poppet valve      (c) spring-loaded disc valve      (d) solenoid valve

67. Ans. (a)

68. Consider the following factors:

1. Cylinder size          2. Clearance ratio  
3. Delivery pressure       4. Compressor shaft power.

The factors which affect the volumetric efficiency of a single-stage reciprocating air compressor would include

(a) 1 and 2        (b) 3 and 4        (c) 2 and 3        (d) 1 and 4

68. Ans. (a) Volumetric efficiency of a single stage reciprocating air compressor is dependent on clearance ratio and cylinder size.
69. The diagram shown in the figure represents reversible compression of air on the p-V co-ordinates. The work of compression needed by a centrifugal compressor is equal to the area
(a) ABDE-ABC
(b) ABDE
(c) ABFG
(d) ABFG-ABC

69. Ans. (b) Work of compression is area below the compression curve AB, i.e. ABDE

70. Performance of a reciprocating compressor is expressed by

- (a) $\frac{\text{Isothermal work}}{\text{Indicated work}}$
- (b) $\frac{\text{Indicated work}}{\text{Isothermal work}}$
- (c) $\frac{\text{Adiabatic work}}{\text{Indicated work}}$
- (d) $\frac{\text{Indicated work}}{\text{Adiabatic work}}$

70. Ans. (a)

71. The isothermal efficiency of a reciprocating compressor is defined as actual work done during compression

- (a) $\frac{\text{actual work done during compression}}{\text{isothermal work done during compression}}$
- (b) $\frac{\text{adiabatic work done during compression}}{\text{isothermal work done during compression}}$
- (c) $\frac{\text{actual work done during compression}}{\text{isothermal work done during compression}}$
- (d) $\frac{\text{isothermal work done during compression}}{\text{actual work done during adiabatic compression}}$

71. Ans. (c)

**Rotary Compressors**

72. A rotary compressor is used when a refrigerating system has to handle a refrigerant with
- (a) low specific volume and high pressure difference
- (b) low specific volume and low pressure difference
- (c) large specific volume and high pressure difference
- (d) large specific volume and low pressure difference

72. Ans. (d)

73. Assertion (A): A vane type rotary compressor is a rotodynamic machine.

Reason (R): A rotodynamic machine is one in which a fluid flows freely through the rotating part of the machine.

73. Ans. (a)
74. The inlet and exit velocity diagrams of a turbo-machine rotor are shown. This turbo-machine is
(a) an axial compressor with backward curved blades  
(b) a radial compressor with backward curved blades  
(c) a radial compressor with forward curved blades  
(d) an axial compressor with forward curved blades
74. Ans. (c)

Screw Compressors

Centrifugal Compressors

75. In the centrifugal air compressor design practice, the value of polytropic exponent of compression is generally taken as
(a) 1.2    (b) 1.3    (c) 1.4    (d) 1.5
75. Ans. (c)

76. What does application of centrifugal air compressors lead to?
(a) Large frontal area of aircraft  
(b) Higher flow rate through the engine  
(c) Higher aircraft speed  
(d) Lower frontal area of the aircraft
76. Ans. (a)

77. In a centrifugal compressor, how can the pressure ratio be increased?
(a) Only by increasing the tip speed  
(b) Only by decreasing the inlet temperature  
(c) By both (a) and (b)  
(d) Only by increasing the inlet temperature
78. Ans. (c)

79. The pressure rise in the impeller of centrifugal compressor is achieved by
(a) the decrease in volume and diffusion action  
(b) the centrifugal action and decrease in volume  
(c) the centrifugal and diffusion action  
(d) the centrifugal and push-pull action
79. Ans. (c)
79. Ans. (c)

80. The flow in the vane less space between the impeller exit and diffuser inlet of a centrifugal compressor can be assumed as (a) free vortex (b) forced vortex (c) solid body rotation (d) logarithmic spiral
80. Ans. (b)

81. Consider the following statements
In centrifugal compressors, there is a tendency of increasing surge when
1. the number of diffuser vanes is less than the number of impeller vanes
2. the number of diffuser vanes is greater than the number of impeller vanes
3. the number of diffuser vanes is equal to the number of impeller vanes
4. mass flow is greatly in excess of that corresponding to the design mass flow
Which of these statements is/are correct?
(a) 1 and 4 (b) 2 alone (c) 3 and 4 (d) 2 and 4
81. Ans. (d)

82. In a radial blade centrifugal compressor, the velocity of blade tip is 400 m/s and slip factor is 0.9. Assuming the absolute velocity at inlet to be axial, what is the work done per kg of flow? (a) 36 kJ (b) 72 kJ (c) 144 kJ (d) 360 kJ
82. Ans. (c)

83. In centrifugal compressor terminology, vane less space refers to the space between (a) the inlet and blade inlet edge (b) blades in the impeller (c) diffuser exit and volute casing (d) impeller tip and diffuser inlet edge
83. Ans. (d) The vane less shape refers to space between impeller tip and diffuser inlet edge.

84. Centrifugal compressors are suitable for large discharge and wider mass flow range, but at a relatively low discharge pressure of the order of 10 bars, because of
(a) low pressure ratio (b) limitation of size of receiver (c) large speeds (d) high compression index
84. Ans. (a) Pressure ratio is low for centrifugal compressors

85. Given: $V_{w2} = \text{velocity of whirl at outlet}$
\[ u_2 = \text{peripheral velocity of the blade tips} \]
the degree of reaction in a centrifugal compressor is equal to
\[ (a) 1 - \frac{V_{w2}}{2u_2} \quad (b) 1 - \frac{u_2}{2V_{w2}} \quad (c) 1 - \frac{2V_{w2}}{u_2} \quad (d) 1 - \frac{V_{w2}}{u_2} \]
85. Ans. (a)

86. For large tonnage (more than 200 tons) air-conditioning applications, which one of the following types of compressors is recommended?
(a) Reciprocating (b) Rotating (c) Centrifugal (d) Screw.
86. Ans. (d) For large tonnage air conditioning applications, specially built centrifugal compressors are used
87. In a centrifugal compressor assuming the same overall dimensions, blade inlet angle and rotational speeds, which of the following bladings will give the maximum pressure rise?
(a) Forward curved blades    (b) Backward curved blades.    [IES-1995]
(c) Radial blades            (d) All three types of bladings have the same pressure rise.
87. Ans. (a) Forward curved blades give maximum pressure rise.

88. In a centrifugal compressor, the highest Mach number leading to shockwave in the fluid flow occurs at
(a) diffuser inlet radius    (b) diffuser outlet radius
(c) impeller inlet radius    (d) impeller outer radius.
88. Ans. (b)

89. If two geometrically similar impellers of a centrifugal compressor are operated at the same speed, then their head, discharge and power will vary with their diameter ratio 'd' as
(a) d, d^2 and d^3 respectively    (b) d^2, d^3 and d^5 respectively.
(c) d, d^3 and d^5 respectively    (d) d^2, d and d^3 respectively.
89. Ans. (d) Head, discharge and power are proportional to d^2, d and d^3    [IES-1994]

90. The stagnation pressure rise in a centrifugal compressor stage takes place.
(a) only in the diffuser    (b) in the diffuser and impeller.    [IES-1994]
(c) only in the impeller    (d) only in the inlet guide vanes.
90. Ans. (a)

91. The specific speed of a centrifugal compressor is generally
(a) higher than that of an axial compressor
(b) less than that of a reciprocating compressor
(c) independent of the type of compressor, but depends only on the size of the compressor
(d) more than the specific speed of the reciprocating compressor but less that of the axial compressor
91. Ans. (d)

92. A multistage compressor is to be designed for a given flow rate and pressure ratio. If the compressor consists of axial flow stages followed by centrifugal instead of only axial flow stages, then the
(a) overall diameter would be decreased    (b) overall diameter would be increased
(c) axial length of the compressor would be increased
(d) axial length of the compressor would be decreased
92. Ans. (b) In case of axial flow stages, diameter will be less and same but in case of centrifugal compressor, the flow is radial at outlet and thus overall diameter will increase.

93. When the outlet angle from the rotor of a centrifugal compressor is more than 90, then the blades are said to be
(a) forward curved    (b) backward curved
(c) radial            (d) either backward or forward curved
93. Ans. (a)
Performance Characteristics of Centrifugal Compressors

94. Which one of the following expresses the isentropic efficiency \( \eta \) of the compression process in terms of enthalpy changes as indicated in the figure given above?

(a) \( \eta = \frac{\Delta H_s}{\Delta H} \)  
(b) \( \eta = \frac{\Delta H}{\Delta H_s} \)

(c) \( \eta = \frac{(\Delta H - \Delta H_s)}{\Delta H} \)

(d) \( \eta = \frac{(\Delta H - \Delta H_s)}{\Delta H_s} \)

94. Ans. (a)

95. Which portion of the centrifugal compressor characteristics shown in the figure is difficult to obtain experimentally?

(a) RS  
(b) ST  
(c) TU  
(d) UV

95. Ans. (a)

96. For centrifugal compressors, which one of the following is the correct relationship between pressure coefficient (\( \phi_p \)) slip factor (\( \phi_s \)) work input factor (\( \phi_w \)) and isentropic efficiency (\( \eta_a \))?

(a) \( \phi_p = \frac{\phi_s \times \phi_w}{\eta_a} \)  
(b) \( \phi_p = \frac{\phi_s}{\phi_s \times \eta_a} \)  
(c) \( \phi_p = \phi_s \times \phi_w \times \eta_a \)  
(d) \( \phi_p = \frac{\phi_s \times \eta_a}{\phi_w} \)

96. Ans. (c)

97. Which one of the following is the effect of blade shape on performance of a centrifugal compressor?

(a) Backward curved blade has poor efficiency.  
(b) Forward curved blade has higher efficiency.  
(c) Backward curved blades lead to stable performance.  
(d) Forward curved blades produce lower pressure ratio

97. Ans. (c)
97. Ans. (c) In centrifugal compressor, backward curved blades lead to stable performance.

98. The curve in the given figure shows the variation of theoretical pressure ratio with mass of flow rate for a compressor running at a constant speed. The permissible operating range of the compressor is represented by the part of the curve from (a) A to B  (b) B to C  (c) B to D  (d) D to E

98. Ans. (c) Curve B to D represents permissible operating range of compressor.

99. Air \( (C_p = 1 \text{ KJ}, \gamma = 1.4) \) enters a compressor at a temperature of 27°C, the compressor pressure ratio is 4. Assuming an efficiency of 80 %, the compressor work required in KJ/Kg is

99. Ans. (c): 
\[
W_{\text{ideal}} = \frac{\gamma}{\gamma - 1} (P_1V_1 - P_2V_2) = \frac{\gamma}{\gamma - 1} P_1V_1 \left[ \left( \frac{P}{P_i} \right)^{\frac{\gamma}{\gamma - 1}} - 1 \right]
\]
\[
= \frac{\gamma}{\gamma - 1} RT_1 \left[ \left( \frac{P}{P_i} \right)^{\frac{\gamma}{\gamma - 1}} - 1 \right] = C_pT_1 \left[ \left( \frac{P}{P_i} \right)^{\frac{\gamma}{\gamma - 1}} - 1 \right] = 1 \times 300 \left[ \frac{4^{0.4/1.4} - 1}{1} \right] = 146
\]
\[
W_{\text{actual}} = \frac{W_{\text{ideal}}}{\eta} = \frac{146}{0.8} = 182
\]

Comparison of Performance of Reciprocating and Centrifugal

Axial flow compressor

100. In an axial flow compressor, when the degree of reaction is 50%, it implies that (a) Work done in compression will be the least  \([\text{IES-2006}]\) (b) 50% stages of the compressor will be ineffective (c) Pressure after compression will be optimum (d) The compressor will have symmetrical blades

100. Ans. (d)

101. Consider the following statements: \([\text{IES-2006}]\)

For a large aviation gas turbine an axial flow compressor is usually preferred over centrifugal compressor because

1. the maximum efficiency is higher.  
2. the frontal area is lower.
3. the pressure rise per stage is more.  4. the cost is lower.
Which of the statements given above are correct?
(a) 1 and 4  (b) Only 1 and 2  (c) 1, 2 and 3  (d) 2, 3 and 4
101. Ans. (b)

102. While flowing through the rotor blades in an axial flow air compressor, the relative velocity of air:
(a) Continuously decreases  (b) Continuously increases
(c) First increases and then decreases  (d) First decreases and then increases
102. Ans. (a)

103. Which one of the following is the correct expression for the degree of reaction for an axial-flow air compressor?  
(a) Work input to the rotor  
Work input to the stage
(b) Change of enthalpy in the rotor  
Change of enthalpy in the stage
(c) Pressure rise in the rotor  
Pressure rise in the stage
(d) Isentropic work  
Actual work
103. Ans. (c)

104. If the static temperature rise in the rotor and stator respectively are $\Delta T_A$ and $\Delta T_B$, the degree of reaction in an axial flow compressor is given by
(a) $\Delta T_A / \Delta T_B$  (b) $\Delta T_A / (\Delta T_A + \Delta T_B)$  (c) $\Delta T_B / (\Delta T_A + \Delta T_B)$  (d) $\Delta T_B / \Delta T_A$
104. Ans. (b)

Degree of reaction of axial flow compressor = $\frac{\text{static temperature rise in rotor}}{\text{static temperature rise in stage}} = \frac{\Delta T_A}{\Delta T_A + \Delta T_B}$

105. Degree of reaction in an axial compressor is defined as the ratio of static enthalpy rise in the
(a) rotor to static enthalpy rise in the stator.  (b) stator to static enthalpy rise in the rotor.  
(c) rotor to static enthalpy rise in the stage.  (d) stator to static enthalpy rise in the stage.  
105. Ans. (c)

106. Compared to axial compressors centrifugal compressors are more suitable for
(a) high head, low flow rate  (b) low head, low flow rate  
(c) low head, high flow rate  (d) high head, high flow rate  
106. Ans. (c)

107. Stalling of blades in axial-flow compressor is the phenomenon of
(a) air stream blocking the passage  (b) motion of air at sonic velocity  
(c) unsteady, periodic and reversed flow  (d) air stream not able to follow the blade contour  
107. Ans. (d)

108. In an axial flow compressor
$\alpha_1 =$ exit angle from stator  $\beta_1 =$ inlet angle to rotor
$\alpha_2 =$ inlet angle to stator  $\beta_2 =$ outlet angle from rotor

[IES-2004]
The condition to have a 50% degree of reaction is
(a) $\alpha_1 = \beta_2$  (b) $\alpha_2 = \beta_1$  (c) $\alpha_1 = \beta_2$ and $\beta_1 = \alpha_2$  (d) $\alpha_1 = \alpha_2$ and $\beta_1 = \beta_2$

108. Ans. (c)

109. In an axial flow compressor design, velocity diagrams are constructed from the experimental data of aerofoil cascades. Which one of the following statements in this regard is correct?

(a) Incidence angle of the approaching air is measured from the trailing edge of the blade  
(b) $\delta$ is the deviation angle between the angle of incidence and tangent to the camber line.  
(c) The deflection $\varepsilon$ of the gas stream while passing through the cascade is given by $\varepsilon = \alpha_1 - \alpha_2$  
(d) $\varepsilon$ is the sum of the angle of incidence and camber less any deviation angle, i.e., $\varepsilon = i + \theta - \delta$

109. Ans. (a)

110. The turbo machine used to circulate refrigerant in a large refrigeration plant is  
(a) a centrifugal compressor  
(b) a radial turbine  
(c) an axial compressor  
(d) an axial turbine

110. Ans. (c)

111. The energy transfer process is  
(a) continuous in a reciprocating compressor and intermittent in an axial compressor  
(b) continuous in an axial compressor and intermittent in a reciprocating compressor  
(c) continuous in both reciprocating and axial compressors  
(d) intermittent in both reciprocating and axial compressors

111. Ans. (c)

112. In an axial flow compressor stage, air enters and leaves the stage axially. If the whirl component of the air leaving the rotor is half the mean peripheral velocity of the rotor blades, then the degree of reaction will be  
(a) 1.00  
(b) 0.75  
(c) 0.50  
(d) 0.25

112. Ans. (d)  

$\text{Degree of reaction} = \frac{V_f}{2V_b}(\tan \beta_1 + \tan \beta_2)$;  
$\frac{V_f}{V_b} = \frac{1}{2}$  
$\tan \beta_1 = \frac{V_f}{V_b} = \frac{1}{2} = \tan \beta_2$  
$\therefore \text{Degree of reaction} = \frac{1}{2 \times 2}(1) = 0.25$

113. If an axial flow compressor is designed for a constant velocity through all stages, then the area of annulus of the succeeding stages will  
(a) remain the same  
(b) progressively decrease  
(c) progressively increase  
(d) depend upon the number of stages

113. Ans. (a)

114. The inlet and exit velocity diagrams of a turbo-machine rotor are shown in the figure I and figure II respectively.
The turbo-machine is
(a) an axial compressor with radial blades
(b) a radial compressor with radial blades.
(c) a radial compressor with forward curved blades
(d) an axial compressor with forward curved blades.

114. Ans. (a) Velocity diagrams are for axial compressor \( u_1 = u_2 \) with radial blades \( V_r \) and \( V_r' \) are perpendicular to \( u_1 \) and \( u_2 \).

115. In a multi-stage axial flow compressor with equal temperature rise in all stages, the pressure ratio in the subsequent stages
(a) Remains constant  
(b) Increases gradually
(c) Decreases  
(d) Increases rapidly

[IES 2007]

115. Ans. (a)

116. Consider the following statements in respect of axial flow compressor:
1. An axial flow air compressor is often describe as a reversed reaction turbine.
2. With 50% degree of reaction, the velocity diagrams are symmetrical.

Which of the statements given above is/are correct?
(a) 1 only  
(b) 2 only  
(c) Both 1 and 2  
(d) Neither 1 nor 2

[IES 2007]

116. Ans. (c)

117. Stalling phenomena in an axial flow compressor stage is caused due to which one of the following?
(a) Higher mass flow rate than the designed value
(b) Lower mass flow rate than the designed value
(c) Higher mass flow rate or non-uniformity in the blade profile
(d) Lower mass flow rate or non-uniformity in the blade profile

[IES 2007]

117. Ans. (d)

118. Consider the following statements regarding the axial flow in an air compressor:
1. Surging is a local phenomenon while stalling affects the entire compressor.
2. Stalling is a local phenomenon while surging affects the entire compressor.
3. The pressure ratio of an axial compressor stage is smaller than that of a centrifugal compressor stage.

Of these statements are correct
(a) 1, 2 and 3  
(b) 1 and 2  
(c) 2 and 3  
(d) 1 and 3

[IES-2001]

118. Ans. (d)

119. High positive incidence in an axial compressor blade row leads to
(a) suppression of separation of flow on the blade.  
(b) choking of the flow.
(c) separation of flow on the suction side of the blade.
(d) separation of flow on the pressure side of the blade.

[IES-1994]

119. (a)
120. Assertion (A): In axial flow compressors, momentum blading is more efficient than radial flow blading.  
Reason (R): In radial flow blading, the pressure head increases due to centrifugal head. 
120. Ans. (b)

121. Assertion (A): The work required per kg of air flow / min. for axial flow compressors is lower than that for centrifugal compressor for the same pressure ratio.  
Reason (R): The isentropic efficiency of axial flow compressor is much higher than that of a centrifugal compressor.  
121. Ans. (a) Both A and R are correct and R provides right explanation for A.

121. In air-craft gas turbines, the axial flow compressor is preferred because  
(a) of high pressure rise  
(b) it is stall free  
(c) of low frontal area  
(d) of higher thrust  
121. Ans. (c) Axial flow compressor is preferred in aircraft gas turbines because of requirement of low frontal area.

122. In axial flow compressor, exit flow angle deviation from the blade angle is a function of  
(a) blade camber  
(b) space-chord ratio  
(c) both blade camber and space-chord ratio  
(d) blade camber and incidence angle  
122. Ans. (c)

123. Match List-I with List-II (pertaining to blower performance) and select the correct answer using the codes given below the Lists:  
123. Ans. (c)

124. Under which one of the following sets of conditions will a supersonic compressor have the highest efficiency?  
(a) Rotor inlet velocity is supersonic and exit velocity subsonic; stator inlet velocity is subsonic and exit velocity is subsonic.  
(b) Rotor inlet velocity is supersonic and exit velocity subsonic; stator inlet velocity is supersonic and exit velocity is subsonic.  
(c) Rotor inlet velocity is supersonic and exit velocity supersonic; stator inlet velocity is supersonic and exit velocity is subsonic.  
(d) Rotor inlet velocity is supersonic and exit velocity supersonic; stator inlet velocity is subsonic and exit velocity is subsonic.  
124. Ans. (c)

125. Consider the following characteristics:  
1. The fluid enters the pump axially and is discharged radially.  
2. Maximum efficiency may be of the order of 90%.
3. Development of a low head
4. A limited suction capacity
Which of the above characteristics are possessed by axial flow pumps?
(a) 1 and 2  
(b) 2 and 3  
(c) 2 and 4  
(d) 3 and 4  
125. Ans. (b) In Axial flow pumps the fluid both enters and discharged axially.

Flash Chamber
126. The flash chamber in a single stage simple vapour compression cycle [IES-1998]
(a) increases the refrigerating effect  
(b) decreases the refrigerating effect  
(c) increases the work of compression  
(d) has no effect on refrigerating effect  
126. Ans. (d) Flash chamber has no effect on refrigerating effect.

127. Flash chamber is used in refrigeration for which one of the following? [IAS-2007]
(a) Decreasing the pressure during multistage compression  
(b) Increasing the compressor pressure ratio  
(c) Effective intercooling medium for purpose of increasing COP  
(d) Maintaining the same pressure and temperature  
127. Ans. (c)

128. Match List-I with List-II and select the correct answer using the codes given below the Lists:

<table>
<thead>
<tr>
<th>List-I</th>
<th>List-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Bell Colemn refrigeration</td>
<td>1. Compressor</td>
</tr>
<tr>
<td>B. Vapour compression refrigeration</td>
<td>2. Generator</td>
</tr>
<tr>
<td>C. Absorption refrigeration</td>
<td>3. Flash chamber</td>
</tr>
<tr>
<td>D. Jet refrigeration</td>
<td>4. Expansion cylinder</td>
</tr>
</tbody>
</table>

Code: A  B  C  D  A  B  C  D
(a) 1  4  3  2  (b) 4  1  3  2
(c) 1  4  2  3  (d) 4  1  2  3
128. Ans. (d)
Answers with Explanation (Objective)
**Condensers**

**Objective Questions (IES, IAS, GATE)**

**Heat Rejection Ratio**

1. In a vapour compressor refrigeration system, the compressor capacity is 2100 kJ/minute and heat rejection factor is 1.2. What will, respectively be the heat rejected from the condenser and C. O. P?  
   (a) 5040 kJ/minute and 5   
   (b) 2520 kJ/minute and 5   
   (c) 2520 kJ/minute and 4   
   (d) 5040 kJ/minute and 4  
   1. Ans. (b)  

   Heat rejection ratio \( G = \frac{Q_o + W}{Q_o} = 1 + \frac{W}{Q_o} = 1 + \frac{1}{\text{COP}} \)  

   or \( G = 1 + \frac{1}{\text{COP}} \)  

   or 1.2 = 1 + \frac{1}{\text{COP}}  

   or COP = 5  

   given \( W = 210 \text{ kJ/minute} \)  

   \( Q_o + W = 1.2 Q_o = 2520 \text{ kJ/minute} \)

2. A refrigeration plant uses a condenser with heat rejection ratio of 1.2. If the capacity of the plant is 210kJ/min, then what is the value of the COP of the refrigeration plant?  
   (a) 3   
   (b) 5   
   (c) 7   
   (d) 9  
   2. Ans. (b)  

   \( \frac{Q_o}{Q_o} = 1.2 \)   

   or \( \frac{Q_o}{Q_o - Q_2} = \frac{1}{0.2} = 5 = \text{COP} \)

3. Experimental measurements on a refrigeration system indicate that rate of heat extraction by the evaporator, rate of heat rejection in the condenser and rate of heat rejection by the compressor body to environment are 70 kW, 90 kW and 5 kW respectively. The power input (in kW) required to operate the system is  
   (a) 15   
   (b) 20   
   (c) 25   
   (d) 75  
   3. Ans. (c)

**Types of Condensers**

4. For small installations of refrigeration systems (up to 35 kW), which type of condenser is used?  
   (a) Shell and cube type   
   (b) Shell and coil type   
   (c) Double tube type   
   (d) Air cooled type  
   4. Ans. (d)
5. A condenser of a refrigeration system rejects heat at a rate of 120 kW, while its compressor consumes a power of 30 kW. The coefficient of performance of the system would be
(a) $\frac{1}{4}$, (b) $\frac{1}{3}$, (c) 3, (d) 4 [IES-1995]
5. Ans. (b) Heat rejected in condenser = 120 kW; Compressor work = 30 kW; Net refrigeration effect = 120 - 30 = 90 kW.
Therefore COP = $\frac{30}{90} = \frac{1}{3}$

6. A pressure gauge on the discharge side of a refrigerant compressor reads too high. The reasons could be:
1. Lack of cooling water
2. Water temperature being high
3. Dirty condenser surfaces
4. Refrigerant temperature being too high
Of these reasons
(a) 1, 2 and 4 are valid, (a) 1, 2 and 3 are valid
(b) 2, 3 and 4 are valid, (a) 1, 3 and 4 are valid
6. Ans. (b)

7. Assertion (A): Condensers of large refrigerating plants including central air-conditioning systems are invariably water-cooled. [IAS-1996]
Reason (R): Water is available at a temperature lower than that of the surrounding air and has a higher specific heat.
7. Ans. (a)

8. A condenser of refrigeration system rejects heat at a rate of 120 kW, while its compressor consumes a power of 30 kW. The coefficient of performance of the system would be [GATE-1992]
(a) $\frac{1}{4}$, (b) 4, (c) $\frac{1}{3}$, (d) 3
8. Ans. (d)
Answers with Explanation (Objective)
6. Expansion Devices

Objective Questions (IES, IAS, GATE)

Types of Expansion Devices
1. Match List-I (Expansion device) with List-II (Operation) and select the correct answer using the codes given below the lists: [IES-2001]

List-I (Expansion device)    List-II (Operation)
A. Float valve     1. Constant degree of superheat at evaporator exit pressure
B. Automatic expansion   2. Constant degree of superheat at evaporator inlet valve pressure
C. Internally equalized thermostatic expansion valve 3. Constant level of refrigerant in the evaporator expansion valve
D. Externally equalized thermostatic expansion valve 4. Constant pressure in the evaporator expansion valve

Codes:
A    B    C    D     A    B    C    D
(a)  1    2    4    3    (b)  3    2    4    1
(c)  3    4    2    1    (d)  1    4    2    3

1. Ans. (c)

2. An expansion valve is NOT used for reducing pressure in the [IAS-2000]
(a) vapour compression refrigeration cycle  (b) vapour absorption refrigeration cycle
(c) steam-jet refrigeration cycle   (d) gas refrigeration cycle

2. Ans. (d) Steam-jet refrigeration cycle is similar to vapour compression refrigeration cycle where mechanical compressor is substituted by steam ejector or booster.

3. Assertion (A): In vapour compression refrigeration system throttle valve is used and not expansion cylinder. [IES-1995]
Reason (R): Throttling is a constant enthalpy process.
3. Ans. (b) A and R are true. But R is not right reasoning for A.

Automatic or Constant-Pressure Expansion Valve
4. Which one of the following types of expansion valves is suitable for a refrigeration plant operating at constant load? [IAS-2007]
(a) Thermostatic expansion valve   (b) Automatic expansion valve
(c) Capillary tube   (d) none of the above

4. Ans. (b)
5. An automatic expansion value is required to maintain constant 
   (a) pressure in the evaporator  (b) temperature in the freezer  
   (c) pressure in the liquid line    (d) temperature in the condenser
5. Ans. (a)

**Thermostatic-Expansion Valve**

6. The sensing bulb of the thermostatic expansion valve is located at the 
   (a) exit of the evaporator  (b) inlet of the evaporator  
   (c) exit of the condenser  (d) inlet of the condenser
6. Ans. (a)

7. A valve which maintains a constant degree of superheat at the end of the evaporator coil, is called
   (a) automatic expansion valve  (b) high side float valve  
   (c) thermostatic expansion valve  (d) low side float valve
7. Ans. (c)

8. Which one of the following is the most important function of thermostatic expansion valve?
   (a) To control the degree of superheat  (b) To control the evaporator temperature  
   (c) To control the pressure drop  (d) To control the evaporator pressure
8. Ans. (a)

9. Consider the following statements:
   Dry compression in reciprocating compressor is preferred because it
   1. prevent valve damage  
   2. enables use of thermostatic expansion valve. 
   3. minimizes irreversibility in the compressor.
   4. prevents washing out of the lubricating oil from cylinder walls.
   Of these statements:
   (a) 1 and 2 are correct  (b) 2 and 3 are correct  
   (c) 1 and 4 are correct  (d) 3 and 4 are correct
9. Ans. (c)

10. Which one of the following is responsible for the operation of a thermostatic expansion valve? 
    (a) Pressure changes in evaporator  (b) Temperature changes in evaporator  
    (c) Degree of superheat in evaporator  (d) Degree of subcooling in evaporator
10. Ans. (c)

11. A thermostatic expansion value in refrigeration system
    (a) ensures the evaporator completely filled with refrigerant of the load
    (b) is suitable only for constant load system 
    (c) maintains different temperatures in evaporator in proportion to load  
    (d) none of the above.
11. Ans. (a)
Capillary Tube and Its Sizing

12. Consider the following statements: The pressure in a horizontal capillary tube of a refrigeration system decreases due to the
1. frictional resistance offered by the tube wall   2. acceleration of refrigerant in the tube
3. heat transfer from the tube wall       4. decrease in the potential energy
Which of these statements are correct?
(a) 1 and 4   (b) 2, 3 and 4   (c) 1, 2 and 3   (d) 1 and 2
12. Ans. (d)

13. In a domestic refrigerator, a capillary tube controls the flow of refrigerant from the
(a) expansion valve to the evaporator   (b) evaporator to the thermostat [IES-1994]
(c) condenser to the expansion valve   (d) condenser to the evaporator.
13. Ans. (d) In domestic refrigerator, a capillary tube controls the flow of refrigerant from
condenser to evaporator

14. In on-off control refrigeration system, which one of the following expansion devices is
used? [IAS-2004]
(a) Capillary tube   (b) Thermostat
(c) Automatic expansion valve   (d) Float valve
14. Ans. (a)

15. Which of the features of expansion valves in the following lists are correctly
matched? [IAS-2004]
<table>
<thead>
<tr>
<th>Expansion Device</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Capillary tube</td>
<td>Choking</td>
</tr>
<tr>
<td>2. Thermostatic expansion valve</td>
<td>Constant temperature</td>
</tr>
<tr>
<td>3. Automatic Expansion valve</td>
<td>Constant degree of superheat</td>
</tr>
<tr>
<td>4. Float valve</td>
<td>Mass flow rate of refrigerant is proportional to load</td>
</tr>
</tbody>
</table>
Select the correct answer using the codes given below:
(a) 1 and 2   (b) 1 and 3   (c) 1 and 4   (d) 3 and 4
15. Ans. (c)

16. The throttling device used in the domestic refrigerator is [IAS-2002]
(a) internally equalized thermostatic expansion valve
(b) externally equalized thermostatic expansion valve
(c) automatic expansion valve
(d) capillary tube
16. Ans. (d)

17. Consider the following statements: The pressure in a capillary tube of a refrigerator decreases because
1. tube wall offers frictional resistance .
2. refrigerant accelerates in the tube
3. tube transfer the heat
4. Potential energy decreases
Of these statements
(a) 1 and 2 are correct    (b) 1, 2 and 3 are correct
(c) 2 and 4 are correct    (d) 3 and 4 are correct
17. Ans. (a)
18. In the window air conditioner, the expansion device used is [GATE-2004]
(a) capillary tube (b) thermostatic expansion valve
(c) automatic expansion valve (d) float valve
18. Ans. (a)
Answers with Explanation (Objective)
Evaporators

Objective Questions (IES, IAS, GATE)

1. The deposition of frost on evaporator tubes of an air conditioner will result in
(a) decrease in heat transfer  (b) increase in heat transfer  
(c) no change in heat transfer  (d) increase in capacity of evaporator  
1. Ans. (a)

2. When a refrigeration plant is started, the evaporator temperature decreases from room temperature to the required value. During this period, how does the compressor power requirement vary?
(a) It increases continuously  (b) It decreases and then becomes constant  
(c) It increases, reaches a peak and then decreases  (d) It remains constant  
2. Ans. (a)
Gas Cycle Refrigeration

Objective Questions (IES, IAS, GATE)

Limitations of Carnot Cycle with Gas as a Refrigerant
1. Air refrigeration cycle is used in [IES-1998]
   (a) commercial refrigerators   (b) domestic refrigerators
   (c) gas liquefaction    (d) air-conditioning
1. Ans. (a) Air refrigeration cycle finds use in commercial refrigerators.

Reversed Brayton or Joule or Bell Coleman Cycle
2. Match List-I (Process) with List-II (Type) for Bell Coleman or Joule or Reverse Brayton cycle for gas cycle refrigeration and select the correct answer using the codes given below the Lists: [IES-2003]

<table>
<thead>
<tr>
<th>List-I</th>
<th>List-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Compression</td>
<td>1. Isobaric</td>
</tr>
<tr>
<td>B. Heat rejection</td>
<td>2. Isothermal</td>
</tr>
<tr>
<td>C. Expansion</td>
<td>3. Isentropic</td>
</tr>
<tr>
<td>D. Heat absorption</td>
<td>4. Isenthalpic</td>
</tr>
</tbody>
</table>

Codes: A B C D  A B C D
(a)  3 1 4 2 (b)  3 1 3 1
(c)  3 2 3 2 (d)  3 1 2 2
2. Ans. (b)

3. Match List I with List II and select the correct answer using the codes given below lists [IAS 1994]

A. List I
   1. Vapour compression cycle using expansion valve

B. 2. Bell-Coleman cycle (gas compression cycle)
C. 3. Vapour compression cycle using expansion engine

Codes:

<table>
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<tbody>
<tr>
<td>(a)</td>
<td>1</td>
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<td>(d)</td>
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3. Ans. (d)

4. When the Brayton cycle working in the pressure limits of \( p_1 \) and \( p_2 \) is reversed and operated as a refrigerator, what is the ideal value of COP for such a cycle?

(a) \( \left( \frac{p_2}{p_1} \right)^{\gamma-1} - 1 \)

(b) \( \frac{1}{\left( \frac{p_2}{p_1} \right)^{\gamma-1}} - 1 \) [IES 2007]

(c) \( \frac{1}{\left( \frac{p_2}{p_1} \right)^{\gamma-1}} - 1 \)

(d) None of the above

4. Ans. (c) \( \eta_{H,E} = 1 - \frac{1}{r_p^{(\gamma-1)/\gamma}} \) \( \therefore \) \( (\text{COP})_{H,P} = \frac{1}{\eta_{H,E}} = \frac{r_p^{\gamma-1}}{r_p^{\gamma-1} - 1} \)

\( (\text{COP})_R = (\text{COP})_{H,P} - 1 = \frac{1}{r_p^{\gamma-1} - 1} = \frac{1}{\left( \frac{p_2}{p_1} \right)^{\gamma-1} - 1} \)
Application to Aircraft Refrigeration

5. While designing the refrigeration system of an aircraft prime consideration is that the 
(a) system has high C.O.P.  (b) H.P./ton is low  [IES-1993]
(c) weight of refrigerant circulated in the system is low
(d) weight of the refrigeration equipment is low.
5. Ans. (d)

The Joule- Thomson Coefficient and Inversion Curve

Reversed Stirling Cycle
Answers with Explanation (Objective)
Vapour-Absorption System

Objective Questions (IES, IAS, GATE)

Simple Vapour-Absorption System

1. In a vapour absorption refrigerator, heat is rejected in:
   (a) Condenser only    (b) Generator only
   (c) Absorber only    (d) Condenser and absorber
   1. Ans. (d)

2. The most common type of absorption system in use in industrial applications is based on the refrigerant - absorbent combination of
   (a) air-water    (b) lithium bromide-air
   (c) carbon dioxide-water    (d) ammonia-water
   2. Ans. (b) Industrial applications use lithium bromide-water combination for absorption refrigeration units.

3. Solar energy can be directly used in
   (a) vapour compression refrigeration system (b) vapour absorption refrigeration system
   (c) air refrigeration system    (d) jet refrigeration system
   3. Ans. (b)

4. Vapour absorption refrigeration system works using the
   (a) ability of a substance to get easily condensed or evaporated
   (b) ability of a vapour to get compressed or expanded
   (c) affinity of a substance for another substance
   (d) absorptivity of a substance
   4. Ans. (c) Vapour absorption refrigeration system works using the affinity of a substance for another substance.

5. Which one of the following statements regarding ammonia absorption system is correct ?
   The solubility of ammonia in water is
   (a) a function of the temperature and pressure of the solution
   (b) a function of the pressure of the solution irrespective of the temperature
   (c) a function of the temperature of the solution alone
   (d) independent of the temperature and pressure of the solution
   5. Ans. (a) The solubility of ammonia in water is a function of temperature and pressure of the solution.

6. The refrigerant used for absorption refrigerators working heat from solar collectors is a mixture of water and

   [IES-2006]

   [IES-1999]

   [IES-1997]

   [IES-1996]
(a) carbon dioxide  (b) sulphur dioxide  (c) lithium bromide  (d) freon 12.
6. Ans. (c) The refrigerant used for absorption refrigerators working on heat from solar collectors is a mixture of water and lithium bromide

7. Waste heat can be effectively used in which one of the following refrigeration systems?
(a) Vapour compression cycle  (b) Vapour absorption cycle.
(c) Air refrigeration cycle  (d) Vortex refrigeration system.  [IES-1995]
7. Ans. (b) Waste heat can be utilized in vapour absorption cycle.

8. Match List I (Basic components of Aqua-ammonia refrigeration system) with List II (functions of the components in the system) and select the correct answer using the codes given below the lists:  [IES-1995]

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Generator</td>
<td>1. Dehydration</td>
</tr>
<tr>
<td>B. Analyzer</td>
<td>2. Removal of vapour from strong aqua-ammonia solution</td>
</tr>
<tr>
<td>C. Rectifier</td>
<td>3. Producing dry ammonia vapour by removing traces of water particles completely</td>
</tr>
<tr>
<td>D. Receiver</td>
<td>4. Storage of high pressure liquid ammonia</td>
</tr>
<tr>
<td>A B C D</td>
<td>A B C D</td>
</tr>
<tr>
<td>(a) 3 1 2 4</td>
<td>(b) 5 3 4 2</td>
</tr>
<tr>
<td>(c) 1 3 2 5</td>
<td>(d) 2 1 3 4</td>
</tr>
</tbody>
</table>
8. Ans. (d)

9. Absorbent in a vapour absorption refrigeration system separates from the refrigerant only when it  [IAS-2007]
(a) Is sufficiently heated  (b) Is sprayed on cooling water
(c) Is cooled  (d) Reacts with refrigerant
9. Ans. (a)

10. The function of a compressor in a vapour absorption system is performed by the  [IAS-2000]
(a) absorber  (b) absorber and pump
(c) pump and generator  (d) absorber, pump & generator
10. Ans. (d)

11. In the absorption refrigeration cycle, the compressor of the vapour compression refrigeration cycle is replaced by  [IAS 1994]
(a) liquid pump  (b) generator
(c) absorber and generator  (d) absorber, liquid pump and generator
11. Ans. (d) The compressor of vapour compression refrigeration cycle is replaced by absorber, liquid pump and generator in the absorption refrigeration cycle.

12. List I   List II  [GATE-1997]
(A) Liquid to suction heat exchanger  1. Vapour absorption refrigeration
(B) Constant volume heat addition  2. Vapour compression refrigeration
(C) Normal shock  3. Diesel cycle
(D) Ammonia water  4. Otto cycle
5. Converging nozzle
6. Converging-diverging nozzle
12. Ans. (A) -2, (B) -4, (C)-6, (D)-1

13. A vapour absorption refrigeration system is a heat pump with three thermal reservoirs as shown in the figure. A refrigeration effect of 100 W is required at 250 K when the heat source available is at 400 K. Heat rejection occurs at 300 K. The minimum value of heat required (in W) is (a) 167, (b) 100, (c) 80, (d) 20. [GATE-2005]

\[\begin{align*}
\text{Heat required} &= 100 - 100 \times 250 = 100 \times \frac{400 - 300}{250 - 400} = 80 W
\end{align*}\]

14. List I | List II
(A) Liquid to suction heat exchanger | 1. Vapour absorption refrigeration
(B) Constant volume heat addition | 2. Vapour compression refrigeration
(C) Normal shock | 3. Diesel cycle
(D) Ammonia water | 4. Otto cycle
5. Converging nozzle
6. Converging-diverging nozzle

14. Ans. (A) -2, (B) -4, (C)-6, (D)-1 [GATE-1997]

**Maximum Coefficient of Performance of a Heat Operated Refrigerating Machine**

15. Maximum possible COP of a solar absorption refrigeration system with generator temperature of 360 K, absorber temperature of 300 K, condenser temperature of 300 K and evaporator temperature of 270 K is (a) 9, (b) 6, (c) 3, (d) 1.5. [IES-2002]

15. Ans. (d)

16. A solar-absorption refrigeration system has generator temperature of 87° C, evaporator temperature of -3° C, condenser and absorber temperatures of 27° C each, then its maximum possible COP is [IES-2001]
17. A reversible heat engine runs between high temperature \( T_1 \) and low temperature \( T_2 \). The work output of this heat engine is used to run reversible refrigeration cycle absorbing heat at temperature \( T_3 \) and rejecting at temperature \( T_2 \). What is the COP of the combined system? 

\[
\begin{align*}
(\text{a}) & \quad \left( \frac{T_1 - T_2}{T_1} \right) \left( \frac{T_3}{T_2 - T_3} \right) \\
(\text{b}) & \quad \left( \frac{T_2}{T_1 - T_2} \right) \left( \frac{T_3 - T_2}{T_3} \right) \\
(\text{c}) & \quad \left( \frac{T_1}{T_1 - T_2} \right) \left( \frac{T_3}{T_2 - T_3} \right) \\
(\text{d}) & \quad \left( \frac{T_3}{T_1 - T_3} \right) \left( \frac{T_1}{T_1 - T_1} \right)
\end{align*}
\]

17. Ans. (a)

\[
Q_1 = \frac{Q_1}{T_2} = \frac{Q_1 - Q_3}{T_1 - T_2} = \frac{W}{T_1 - T_2} \quad \text{or} \quad W = \frac{Q_1}{T_1} \times (T_1 - T_2) \\
Q_3 = \frac{Q_3}{T_3} = \frac{Q_3 - Q_3}{T_2 - T_3} = \frac{W}{T_2 - T_3} \quad \text{or} \quad W = \frac{Q_3}{T_3} \times (T_2 - T_3) \\
\text{or} \quad \frac{Q_1}{Q_1} (T_1 - T_2) = \frac{Q_3}{T_3} (T_1 - T_3) \\
\text{or} \quad \text{COP} = \frac{Q_1}{Q_1} = \left( \frac{T_3}{T_2 - T_3} \right) \times \left( \frac{T_1 - T_2}{T_1} \right)
\]

18. The maximum COP for the absorption cycle is given by (\( T_G = \) generator temperature, \( T_c = \) environment temperature, \( T_E = \) refrigerated space temperature) [IES-1998]

\[
\begin{align*}
(\text{a}) & \quad \frac{T_E}{T_G} \left( \frac{T_G - T_E}{T_c - T_E} \right) \\
(\text{b}) & \quad \frac{T_G}{T_c} \left( \frac{T_c - T_E}{T_G - T_c} \right) \\
(\text{c}) & \quad \frac{T_c}{T_G} \left( \frac{T_G - T_c}{T_c - T_E} \right) \\
(\text{d}) & \quad \frac{T_G}{T_E} \left( \frac{T_E - T_G}{T_G - T_E} \right)
\end{align*}
\]

18. Ans. (a)

19. Theoretical maximum C.O.P. of a vapour absorption system (where, \( T_G = \) generator temp, \( T_E = \) evaporator temp, \( T_o = \) environmental temp) is [IES-2003]

\[
\begin{align*}
(\text{a}) & \quad \frac{T_E}{T_G} \left( \frac{T_G - T_o}{T_o - T_E} \right) \\
(\text{b}) & \quad \frac{T_E}{T_o} \left( \frac{T_o - T_E}{T_o - T_E} \right) \\
(\text{c}) & \quad \frac{T_o}{T_E} \left( \frac{T_E - T_o}{T_o - T_E} \right) \\
(\text{d}) & \quad \frac{T_G}{T_E} \left( \frac{T_o - T_E}{T_o - T_E} \right)
\end{align*}
\]

19. Ans. (a)

20. A heat engine having an efficiency of 70% is used to drive a refrigerator having a coefficient of performance of 5. The energy absorbed from low temperature reservoir by the refrigerator for each kJ of energy absorbed from high temperature source by the engine is [GATE-2004]
20. Ans. (c)

\[ \frac{Q_{\text{in}}}{Q_{\text{out}}} = 0.7 \cdot (\text{C.O.P})_b = 5 \]

Given:
\[ Q_{\text{in}} = \frac{W}{\text{C.O.P}} \]

Now,
\[ \text{C.O.P} = \frac{Q_{\text{in}}}{W} \]

Also,
\[ W = \frac{Q_{\text{in}}}{5} \]

Again,
\[ 0.7 = \frac{Q_{\text{in}}}{5} + \frac{1}{Q_{\text{in}}} \]

Energy absorbed from low temperature reservoir by the refrigerator for each 1 J of energy absorbed from high temperature source by the engine = 3.5 J.

21. For the same condenser and evaporator temperatures, the COP of absorption refrigeration system is less than that of mechanical vapour compression refrigeration system, since in the absorption refrigeration system, [IAS-1997]
(a) a liquid pump is used for compression
(b) a refrigerant as well as a solvent is used
(c) absorber requires heat rejection
(d) low grade energy is used to run the system
21. Ans. (d)

22. Air cooling is used for freon compressors whereas water jacketing is adopted for cooling ammonia compressors. This is because [IES-1997]
(a) latent heat of ammonia is higher than that of freon
(b) thermal conductivity of water is higher than that of air
(c) specific heat of water is higher than that of air
(d) of the larger superheat horn of ammonia compression cycle.
22. Ans. (a) Because of high latent heat of ammonia water cooling is required to remove large heat

### Representation of Vapour Absorption Cycle on In Practical Single-Effect Water-Lithium

23. A vapour absorption refrigeration system is a heat pump with three thermal reservoirs as shown in the figure. A refrigeration effect of 100 W is required at 250 K when the heat source available is at 400 K. Heat rejection occurs at 300 K. The minimum value of heat required (in W) is
(a) 167                (b) 100                (c) 80                (d) 20

23. Ans. (c)
Double-effect H₂O - LiBr Absorption System

Electrolux Refrigerator

24. In an Electrolux refrigerator: (a) Ammonia is absorbed in water (b) Ammonia is absorbed in hydrogen (c) Hydrogen is evaporated in ammonia (d) Ammonia evaporated in hydrogen

24. Ans. (d)

25. Hydrogen is essential in an Electrolux refrigeration system, because (a) it acts as a catalyst in the evaporator (b) the reaction between hydrogen and ammonia is endothermic in evaporator and exothermic in absorber (c) the cooled hydrogen leaving the heat exchanger cools the refrigerant entering the evaporator (d) it helps in maintaining a low partial pressure for the evaporating ammonia

25. Ans. (d) Hydrogen gas in Electrolux refrigerator helps in maintaining a low partial pressure for the evaporating ammonia
Answers with Explanation (Objective)
10. Ejector-Compression System

   Water as a Refrigerant
   Steam Ejector System
Psychometry

Objective Questions (IES, IAS, GATE)

Psychometric Properties

1. Consider the following statements: [IES-1997]
   A psychrometer measures
   1. wet bulb temperature    2. dew point temperature       3. dry bulb temperature.
   On these statements
   (a) 1 alone is correct      (b) 2 and 3 are correct
   (c) 1 and 3 are correct     (d) 1, 2 and 3 are correct
   1. Ans. (c) A psychrometer measures wet bulb temperature and dry bulb temperature

2. If the specific heats of dry air and water vapour are 1.00 kJ/kg-K and 1.88 kJ/kg-K respectively and the humidity ratio is 0.011, then the specific heat of moist air at 25°C and 50% relative humidity will be [IES-1994]
   (a) 1.0207 kJ/kg-K  (b) 1.869 kJ/kg-K  (c) 1.891 kJ/kg-K  (d) 0.9793 kJ/kg-K
   2. Ans. (a) Specific heat of moist air = specific heat of dry air + humidity ratio x specific heat of water vapour = 1.00 + 0.011 x 1.88 = 1.00 + 0.0207 = 1.0207 kJ/kg°K.

Specific humidity or Humidity ratio

3. The expression \[0.622 \frac{P_v}{P_b - P_v}\], where \(P_v\) = partial pressure of water vapour; [IAS-2001]
   \(P_b\) = atmospheric barometric pressure, is used for calculating
   (a) relative humidity    (b) degree of saturation
   (c) humidity ratio       (d) pressure of air
   3. Ans. (c)

Specific humidity or absolute humidity or humidity ratio \((w) = \frac{0.622 P_v}{P_b - P_v}\) [IES-1998]

4. The expression \[0.622 \frac{P_v}{P_b - P_v}\] is used to determine
   (a) relative humidity    (b) specific humidity
   (c) degree of saturation  (d) partial pressure
   4. Ans. (b)

5. If \(P_a\) and \(P_v\) denote respectively the partial pressure of dry air and that of water vapour in moist air, the specific humidity of air is given by [IES-2001]
5. Ans. (c)

6. When the wet bulb and dry bulb temperatures are equal, which of the following statements is/are correct? [IES-2005]
1. Air is fully saturated.
2. Dew point temperature is reached.
3. Partial pressure of vapour equals to the total pressure.
4. Humidity ratio is 100%.
(a) 1 and 2  (b) 1 only  (c) 1, 2 and 3  (d) 2 and 3
6. Ans. (a)

7. Moist air exists at a pressure of 1.01 bar. The partial pressure and saturation pressure of water vapour are 0.01 bar and 0.02 bar respectively. What are the relative humidity and humidity ratio of the moist air, respectively? [IAS-2004]
(a) 50% and 0.00622  (b) 100% and 0.0126  (c) 50% and 0.0126  (d) 100% and 0.00622
7. Ans. (a)

8. Dew point temperature of air at one atmospheric pressure (1.013 bar) is 18°C. The air dry bulb temperature is 30°C. The saturation pressure of water at 18°C and 30°C are 0.02062 bar and 0.04241 bar respectively. The specific heat of air and water vapour respectively are 1.005 and 1.88 kJ/kg K and the latent heat of vaporization of water at 0°C is 2500 kJ/kg. The specific humidity (kJ/kg of dry air) and enthalpy (kJ/kg of dry air) of this moist air respectively, are [GATE-2004]
(a) 0.01051, 52.64  (b) 0.01291, 63.15  (c) 0.01481, 78.60  (d) 0.01532, 81.40
8. Ans. (a)
Relative humidity

9. The equation $\phi = \frac{p_v}{p_s}$ is used to calculate the ($p_v$ = partial pressure of water vapour in moist air at a given temperature, $p_s$ = saturation pressure of water vapour at the same temperature) [IES-1999]

(a) relative humidity  (b) degree of saturation
(c) specific humidity  (d) absolute humidity

9. Ans. (a)

10. If the volume of moist air with 50% relative humidity is isothermally reduced to half its original volume, then relative humidity of moist air becomes [IES-2003]

(a) 25%  (b) 60%  (c) 75%  (d) 100%

10. Ans. (d)

$$\text{Relative humidity (RH)} = \frac{P_{v1}}{P_s} = 0.5 \quad \text{or} \quad P_{v1} = 0.5 \times P_s$$

Where subscript 'v' refers to vapour state.

Where subscript 's' refers to saturation state.

$$P_{v1} = P_{v1} \times \left( \frac{V_2}{V_1} \right) = (0.5 \times P_s) \times \left( \frac{2V_1}{V_1} \right) = P_s$$

$$\therefore \text{Relative humidity (RH)} = \frac{P_{v1}}{P_s} = \frac{P_s}{P_s} = 100\%$$

11. The wet bulb depression is zero, when relative humidity is equal to: \[\text{IES-2006}\]

(a) 100%  (b) 60%  (c) 40%  (d) Zero

11. Ans. (a)

12. Evaporative air-cooler is used effectively when [IES-1995]

(a) dry bulb temperature is very close to the wet bulb temperature
(b) dry bulb temperature is high and relative humidity is high
(c) dry-bulb temperature is low and relative humidity is high
(d) dry bulb temperature is high and the relative humidity is low.

12. Ans. (d)

13. For which one of the following DBT, WBT and DPT has the same value?

(a) 0 per cent relative humidity line  (b) 100 per cent relative humidity line
(c) 50 per cent relative humidity line  (d) None of the above \[\text{IAS-2007}\]

13. Ans. (b)

14. Match List I (Quantity) with List II (Measuring Device) and select the correct answer using the codes given below the Lists: [IAS-2002]

<table>
<thead>
<tr>
<th>List I (Quantity)</th>
<th>List II (Measuring Device)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Engine speed</td>
<td>1. Manometer</td>
</tr>
<tr>
<td>B. Fuel heating value</td>
<td>2. Tachometer</td>
</tr>
<tr>
<td>C. Air velocity</td>
<td>3. Hydrometer</td>
</tr>
<tr>
<td>D. Relative humidity of air</td>
<td>4. Calorimeter</td>
</tr>
<tr>
<td></td>
<td>5. Hygrometer</td>
</tr>
</tbody>
</table>
14. Ans. (c)

15. If a sample of moist air of 50% relative humidity at atmospheric pressure is isothermally compressed to a pressure of two atmospheres, then
    (a) its relative humidity will reduce to 25%
    (b) its relative humidity will remain unchanged
    (c) the sample of air will become saturated
    (d) saturation pressure will increase to twice the value

    15. Ans. (b) Relative humidity $\phi = \frac{p_v}{p_s}$, Here total pressure increased but partial pressure of water vapour is unchanged so no change in relative humidity

16. A sample of moist air is at a temperature $T$ and relative humidity 50%. Apart of the moisture is removed adiabatically by using an adsorbent. If the heat of adsorption is negligible, the resulting air will have the same
    (a) dry bulb temperature but a lower wet bulb temperature
    (b) wet bulb temperature but a higher dry bulb temperature
    (c) dry bulb temperature but a higher wet bulb temperature
    (d) wet bulb temperature but a lower dry bulb temperature

    16. Ans. (b)

17. For a typical sample of ambient air (at 35 °C, 75% relative humidity and standard atmospheric pressure), the amount of moisture in kg per kg of dry air will be approximately

    (a) 0.002   (b) 0.027   (c) 0.25   (d) 0.75

    17. Ans. (b)

    Here, $\phi = \frac{p_v}{p_s}$

    $\Rightarrow p_v = \phi \cdot p_s$

    $(p_s)_{35^\circ C} = 0.05628 \text{ bar}$

    $\omega = 0.622 \ p_v$

18. For air at a given temperature, as the relative humidity is increased isothermally,
    (a) the wet bulb temperature and specific enthalpy increase
    (b) the wet bulb temperature and specific enthalpy decrease
    (c) the wet bulb temperature increases and specific enthalpy decreases
    (d) the wet bulb temperature decreases and specific enthalpy increases

    18. Ans. (a, c)

**Dew point temperature**

19. The minimum temperature to which water can be cooled in a cooling tower is
    (a) the dew point temperature of air   (b) the wet bulb temperature of air.
19. Ans. (a) Water can be cooled in a cooling tower up to the dew point temperature of air.

20. In a cooling tower, the minimum temperature to which water can be cooled is equal to the
(a) dew point temperature of the air at the inlet  
(b) dry bulb temperature of the air at the inlet  
(c) thermodynamic wet bulb temperature of the air at the inlet  
(d) mean of the dew point and dry bulb temperature of the air at the inlet

20. Ans. (a)

21. In a chilled-water spray pond, the temperature of water is lower than the dew point temperature of entering air. The air passing through the spray undergoes
(a) cooling and humidification  
(b) cooling and dehumidification  
(c) sensible cooling  
(d) dehumidification

21. Ans. (b) In this case condensation of moisture takes place which results in a fall in specific humidity ratio. Cooling and dehumidification take place.

22. When a stream of moist air is passed over a cold and dry cooling coil such that no condensation takes place, then air stream will get cooled along the line of
(a) constant wet bulb temperature  
(b) constant dew point temperature  
(c) constant relative humidity  
(d) constant enthalpy

22. Ans. (b) When a stream of moist air is passed over a cold and dry cooling coil such that no condensation takes place, then air stream is cooled along constant dew point temperature.

23. Evaporative regulation of body temperature fails when the body temperature is
(a) more than wet bulb temperature but less than dry bulb temperature  
(b) more than dew point but less than wet bulb temperature  
(c) more than dew point but less than dry bulb temperature  
(d) less than dew point

23. Ans. (d)

24. Dew point temperature is the temperature at which condensation begins when the air is cooled at constant
(a) volume  
(b) entropy  
(c) pressure  
(d) enthalpy

24. Ans. (c)

Air is cooled at constant pressure to make unsaturated air to saturated one.

25. For air with a relative humidity of 80%
(a) the dry bulb temperature is less than the wet bulb temperature

25. Ans. (a)
(b) the dew point temperature is less than wet bulb temperature
(c) the dew point and wet bulb temperatures are equal
(d) the dry bulb and dew point temperatures are equal
25. Ans. (b)

26. Consider the following statements:
1. Dew point is reached by cooling air at constant moisture content.
2. Wet bulb temperature changes by addition of moisture at constant enthalpy.
3. For saturated air, the dry bulb temperature, wet bulb temperature and dew point are the same.
4. Dehumidification of air is achieved by heating. [IAS-1995]
Of these statements:
(a) 1 and 3 are correct (b) 1 and 2 are correct (c) 3 and 4 are correct (d) 1 alone is correct
26. Ans. (a)

**Degree of saturation**

27. The ratio of weight of water vapour associated with unit weight of dry air to the weight of water vapour associated with unit weight of dry air saturated at the same dry-bulb temperature and pressure is known as [IAS-2000]
(a) specific humidity  (b) relative humidity  (c) absolute humidity (d) degree of saturation
27. Ans. (d)

28. If $P_v$ is the partial pressure of vapour, $P_s$ is the partial pressure of vapour for saturated air and $P_b$ is the barometric pressure, the relationship between relative humidity $\phi$ and degree of saturation $\mu$ is given by [IES-2001]
(a) $\mu = \phi \left( \frac{P_b - P_s}{P_b} \right)$  (b) $\mu = \phi \left( \frac{P_b - P_v}{P_b} \right)$  (c) $\mu = \phi \frac{P_v}{P_b}$  (d) $\mu = \phi \frac{P_v}{P_s}$
28. Ans. (a)

29. Air at state 1 (dpt 1°C, $W = 0.0040$ kg/kg air) mixes with air at state 2 (dpt 18°C, $W = 0.0051$ kg/kg air) in the ratio 1 to 3 by weight. The degree of saturation (%) of the mixture is (the specific humidity of saturated air at 13.6°C, $W = 0.01$ kg/kg air) [IES-1999]
(a) 25  (b) 30  (c) 48  (d) 62
29. Ans. (c)

kg of moisture actually contained in mixture $= \frac{0.004 + 3\times0.0051}{4} = 0.0048$
kg of moisture in saturated air of mixture $= 0.01$ kg/kg of air
So, Degree of saturation $= \frac{0.0048}{0.01} \times 100\% = 48\%$
30. Match List I with List II and select the correct answer using the code given below the Lists:

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Degree of saturation</td>
<td>1. Measure of latent enthalpy of moist air</td>
</tr>
<tr>
<td>B. Dry bulb temperature</td>
<td>2. Measure of total enthalpy of moist air</td>
</tr>
<tr>
<td>C. Wet bulb temperature</td>
<td>3. Measure of the capacity of air to absorb moisture</td>
</tr>
<tr>
<td>D. Dew point temperature</td>
<td>4. Measure of sensible enthalpy of moist air</td>
</tr>
</tbody>
</table>

(a) 2 1 3 4  (b) 3 4 2 1  (c) 2 4 3 1  (d) 3 1 2 4

30. Ans. (b)

31. Consider the following statements:

1. The specific humidity is the ratio of the mass of water vapour to the mass of dry air in a given volume of the mixture
2. The relative humidity of the atmospheric air is the ratio of the actual mass of the water vapour in a given volume to that which it would have if it were saturated at the same temperature
3. The degree of saturation is defined as the ratio of the specific humidity of a mixture to the specific humidity of the mixture when saturated at the same temperature

Which of the statements given above are correct?
(a) 1 and 2  (b) 2 and 3  (c) 1 and 3  (d) 1, 2 and 3

31. Ans. (d)

**Wet Bulb Temperature (WBT)**

32. If wet bulb depression is equal to the sum of range and approach of a cooling tower, then the water

(a) inlet temperature is equal to the wet bulb temperature of ambient air.
(b) outlet temperature is equal to the wet bulb temperature of ambient air.
(c) inlet temperature is equal to dry bulb temperature of ambient air.
(d) outlet temperature is equal to dry bulb temperature of ambient air.

32. Ans. (c)

33. In a cooling tower the sum of range and approach is equal to twice the wet bulb depression. Then

(a) Dry bulb temperature is mean of water inlet temperature and wet bulb temperature
(b) Dry bulb temperature is mean of water outlet temperature and wet bulb temperature
(c) Water inlet temperature is mean of dry bulb temperature and wet bulb temperature
(d) Water inlet temperature is mean of water outlet temperature and wet bulb temperature

33. Ans. (a)
\[ T_i = \text{inlet temperature of water in cooling tower} \]
\[ T_o = \text{outlet temperature of water in cooling tower} \]

Approach = \[ T_o - T_{wb} \]

Wet bulb depression = \[ T_{db} - T_{wb} \]

From the given statement, \[ (T_i - T_o) + (T_o - T_{wb}) = 2 (T_{db} - T_{wb}) \]

or \[ T_{db} = \frac{T_i + T_{wb}}{2} \]

34. In case A, moist air is adiabatically saturated and in case B, moist air is isobarically saturated. The saturation temperatures in cases A and B are respectively
(a) dry bulb temperature and wet bulb temperature
(b) dew point temperature and wet bulb temperature
(c) wet bulb temperature and dew point temperature
(d) wet bulb temperature and dry bulb temperature
34. Ans. (c)

35. Consider the following statements:
When dry bulb and thermodynamic wet bulb temperatures are same;
1. humidity ratio is 100%  
2. partial pressure of water vapour equals total pressure
3. air is fully saturated  
4. dew point temperature is reached

Select the correct statement(s) using the codes given below:
Codes:
(a) 3 alone   (b) 1 and 2   (c) 3 and 4   (d) 1, 2, 3 and 4
35. Ans. (d)

36. At 100% relative humidity, the wet bulb temperature is
(a) more than dew point temperature
(b) same as dew point temperature
(c) less than dew point temperature
(d) equal to ambient temperature.
36. Ans. (c)

37. In a saturated air-water vapour mixture, the
(a) dry bulb temperature is higher than the wet bulb temperature
(b) dew point temperature is lower than the wet bulb temperature
(c) dry bulb, wet bulb and dew point temperatures are the same
(d) dry bulb temperature is higher than the dew point temperature
37. Ans. (c) In a saturated air-water vapour mixture, the dry bulb, wet bulb and dew point temperatures are the same.

38. Consider the following statements:
If moist air is adiabatically saturated in an air washer than
1. wet bulb temperature remains constant
2. relative humidity increases
3. dry bulb temperature decreases
4. humidity ratio decreases
Which of these statements is/are correct?
(a) 1, 2 and 3  
(b) 1, 2 and 4  
(c) 2, 3 and 4  
(d) 1, 3 and 4
38. Ans. (a)
39. Desert coolers are suitable for hot very dry outside conditions because
(a) water is recirculated in the spray
(b) heat is neither added nor removed from the water
(c) wet bulb depression (t-t) is very large
(d) large quantity of air can be conditioned

39. Ans. (c)

40. If the measured wet-bulb temperature and the thermodynamic wet-bulb temperature are equal then the non-dimensional number with a value of unity is the
(a) Lewis number
(b) Prandtl number
(c) Schmidt number
(d) Sherwood number

40. Ans. (a) Le = 0.945

41. When the wet and dry bulb temperatures are identical, which of the following statements is/are true?
1. Air is fully saturated
2. Dew point temperature is reached
3. Humidity ratio is unity
4. Partial pressure of vapour equals total pressure

Select the correct answer from the codes given below:
(a) 1 only
(b) 1 and 2
(c) 3 and 4
(d) 1, 2, 3 and 4

41. Ans. (b)

42. When dry-bulb and wet-bulb temperatures are identical, it means that the
(a) air is fully saturated and dew-point temperature has reached
(b) air is fully saturated
(c) dew-point temperature has reached and humidity is 100%
(d) partial pressure of water vapour is equal to total pressure

42. Ans. (b)

**Adiabatic saturation of air and adiabatic saturation temperature**

43. During adiabatic saturation process of air, wet bulb temperature
(a) increases and dry bulb temperature remains constant
(b) remains constant and dry bulb temperature increases
(c) remains constant and dry bulb temperature decreases
(d) decreases and dry bulb temperature remains constant

43. Ans. (b)

44. During the adiabatic cooling of moist air
(a) DBT remains constant
(b) specific humidity remains constant
(c) relative humidity remains constant
(d) WBT remains constant

44. Ans. (d)

45. Water in an insulated evaporative cooler evaporates at the rate of 0.003 kg/s. Air flow rate is 1 kg/s. What is the air temperature decrease if the specific heat of humid air is 1 kJ/kg K and latent heat of water is 2500 kJ/kg?
(a) 2.5°C
(b) 3.0°C
(c) 7.5°C
(d) 10°C

45. Ans. (c)

Heat balance gives us
\[ \dot{m}_w c_p \Delta T = \dot{m}_w L \]

or
\[ \Delta T = \frac{\dot{m}_w \times L}{\dot{m}_w \times c_p} = \frac{0.003 \times 2500}{1 \times 1} = 7.5°C \]
46. Total heat transfer from a wetted surface depends upon
(a) difference in temperature between surface and air
(b) difference in humidity ratio of air and air saturated at wet surface temperature
(c) difference in enthalpy between saturated air at surface temperature and that of air
(d) difference in entropy between saturated air at surface temperature and that of air
46. Ans. (d)

47. The main process which takes place in a desert-cooler is
(a) sensible cooling (b) dehumidification
(c) adiabatic saturation (d) cooling and dehumidification
47. Ans. (c) In a desert-cooler water vaporize and latent heat of vaporization is cools the air.

**Psychometric Chart**

48. Moist air is a mixture of dry air and water vapour. Hence three independent intrinsic thermodynamic properties are required to fix its thermodynamic state. While using psychometric chart, however, only two thermodynamic properties are needed since, psychometric chart
(a) is an approximation to actual properties
(b) assumes that both water vapour and dry air behave like perfect gases
(c) is drawn for actual properties of water vapour and dry air
(d) is drawn for a fixed pressure
48. Ans. (d) The psychometric chart is drawn for a fixed pressure (standard atmospheric pressure) and thus only two thermodynamic properties are needed to fix thermodynamic state.

49. With respect to the following figure which shows four processes on the psychometric chart, match List I with List II and select the correct answer using the codes given below the lists:

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Process RS</td>
<td>1. Cooling and humidifying</td>
</tr>
<tr>
<td>B. Process RT</td>
<td>2. Sensible heating</td>
</tr>
<tr>
<td>C. Process RU</td>
<td>3. Cooling and dehumidifying</td>
</tr>
<tr>
<td>D. Process RW</td>
<td>4. Humidifying</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Codes:</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>(c)</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

49. Ans. (c)

50. The statements concern psychometric chart.
1. Constant relative humidity lines are uphill straight lines to the right
2. Constant wet bulb temperature lines are downhill straight lines to the right
3. Constant specific volume lines are downhill straight lines to the right
4. Constant enthalpy lines are coincident with constant wet bulb temperature lines
Which of the statements are correct?
(a) 2 and 3  (b) 1 and 2  (c) 1 and 3  (d) 2 and 4
50. Ans. (a)
51. Which one of the following is correct for the process 1-2 shown above?
(a) The partial pressure of water vapour in air remains constant
(b) Specific humidity of air remains constant
(c) Enthalpy of air remains constant
(d) Dry bulb temperature of air remains constant

51. Ans. (c)

52. Which of the following properties increases during sensible heating of air-water vapour-mixture?

1. Relative humidity
2. Humidity ratio
3. Wet bulb temperature
4. Specific enthalpy of air-vapour mixture

Select the correct answer from the codes given below:
(a) 1 and 2  (b) 3 only  (c) 2 and 3  (d) 3 and 4

52. Ans. (d)

53. Atmospheric air at 35°C and 60% RH can be brought to 20°C and 60% RH by:
(a) Cooling and dehumidification process
(b) Cooling and humidification process
(c) Adiabatic saturation process
(d) Sensible cooling process

53. Ans. (a)

1-2 = 1-2' + 2'-2
cooling + de-humidification

54. Assertion (A): On the psychometric chart, constant enthalpy lines and constant wet bulb lines are the same.
54. Ans. (a) Both A and R are true and R is the correct explanation of A

55. Ans. (b) Psychometric chart is plotted for standard atmospheric pressure and as such only 2 coordinates are used to fix the state point. For pressures other than standard atmospheric, some correction is required.

56. Ans. (c)

57. Ans. (b)

58. Ans. (b)
During sensible heating
1. moisture content increases
2. dry bulb temperature and wet bulb temperature increase
3. dew point remains constant
4. relative humidity increases
Select the correct answer using the codes given below:
(a) 1, 2 and 3  (b) 2, 3 and 4  (c) 2 and 3  (d) 1 and 2
60. Ans. (c) During sensible heating, dry bulb temperature and wet bulb temperature increase, dew point remains unchanged. Moisture content remains same and relative humidity decreases. This statements 2 and 3 are correct

61. Match List I with List II and select the correct answer using the codes given below the lists:

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Steam spray into air</td>
<td>1. Sensible cooling</td>
</tr>
<tr>
<td>B. Air passing over a coil carrying steam</td>
<td>2. Cooling and dehumidification</td>
</tr>
<tr>
<td>C. Air passing over coil having temperature less than dew point</td>
<td>3. Heating and humidification</td>
</tr>
<tr>
<td>D. Air passing over a coil having temperature above the dew point but below the wbt</td>
<td>4. Sensible heating</td>
</tr>
</tbody>
</table>

Codes:   A B C D  A B C D
(a) 2 1 3 4 (b) 3 1 2 4
(c) 3 4 2 1 (d) 4 3 2 1
61. Ans. (c)

62. When moist air comes into contact with a wetted surface whose temperature is less than the dry-bulb temperature but more than the wet-bulb temperature?  [IAS-2000]
(a) sensible, latent and net heat transfers are from air to surface
(b) both sensible and net heat transfers are from air to surface but latent heat transfer is from surface to air
(c) sensible heat transfer is from air to surface but both latent and net heat transfers are from surface to air
(d) sensible heat transfer is from surface to air but both latent and net heat transfers are from air to surface.
62. Ans. (b)

63. When atmospheric air is heated at constant pressure, its  [GATE-2000]
(a) humidity ratio does not change  (b) relative humidity increases
(c) dew point temperature does not change  (d) wet bulb temperature increases
63. Ans. (a, c)

**Sensible cooling**

64. During sensible cooling of air,  [IES-1998]
(a) its wet bulb temperature increases and dew point remains constant
(b) its wet bulb temperature decreases and the dew point remains constant
(c) its wet bulb temperature increases and the dew point decreases
(d) its wet bulb temperature decreases and dew point increases
64. Ans. (b) During sensible cooling of air, its wet bulb temperature decreases but dew point remains unchanged.
65. During sensible cooling
(a) Relative humidity remains constant
(b) Wet bulb temperature increases
(c) Specific humidity increases
(d) Partial pressure of vapour remains constant.
65. Ans. (d)

66. If moist air is sensibly cooled above its dew point, which of the following statements are correct? [IAS-2004]
1. Relative humidity decreases.
2. Wet bulb temperature decreases.
3. Wet bulb temperature increases.
4. Humidity ratio remains constant.
Select the correct answer using the codes given below:
Codes:
(a) 1 and 2
(b) 1 and 3
(c) 3 and 4
(d) 2 and 4
66. Ans. (d)

Humidification

Dehumidification
67. When warm saturated air is cooled [IES-2000]
(a) excess moisture condenses
(b) excess moisture condenses but relative humidity remains unchanged
(c) excess moisture condenses and specific humidity increases but relative humidity remains unchanged.
(d) specific humidity increases and relative humidity decreases
67. Ans. (a)

Chemical Dehumidification
68. Consider the following statements: [IES-1993]
In chemical dehumidification process
1. dew point temperature decreases
2. wet bulb temperature decreases
3. dry bulb temperature increases.

Of these statements
(a) 1, 2 and 3 are correct
(b) 1 and 2 are correct
(c) 2 and 3 are correct
(d) 1 and 3 are correct
68. Ans. (b) Statements 1 and 2 are correct because dry bulb temperature remains constant in dehumidification process.

69. During chemical dehumidification [IAS-1996]
(a) wet bulb temperature constant but enthalpy changes
(b) dry bulb temperature remains constant
(c) both dew point and web bulb temperature remain constant
(d) enthalpy and web bulb temperature remain constant
69. Ans. (d)

70. During chemical dehumidification process of air [GATE-2004]
(a) dry bulb temperature and specific humidity decrease
(b) dry bulb temperature increases and specific humidity decreases
(c) dry bulb temperature decreases and specific humidity increases
(d) dry bulb temperature and specific humidity increase
70. Ans. (b)
71. Select statements from List II matching the processes in List I. Enter your answer as D,C if the correct choice for (1) is D and that for (2) is (C) [GATE-1999]

<table>
<thead>
<tr>
<th>List I</th>
<th>List II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Cooling and dehumidification</td>
<td>(A) Dry bulb temperature increases, but dew - point temperature decreases.</td>
</tr>
<tr>
<td>(b) Chemical dehumidification</td>
<td>(B) Dew - point temperature increases and dry - bulb temperature remains uncharged</td>
</tr>
<tr>
<td></td>
<td>(C) Dry - bulb and wet - bulb temperatures decrease</td>
</tr>
<tr>
<td></td>
<td>(D) Dry - bulb temperature decreases, but, dew - point temperature increases</td>
</tr>
</tbody>
</table>

71. Ans. (c, d)

72. Which one of the following statement is correct? [IAS-2003]
(a) Dehumidifier coil surface temperature is above both the dew point temperature but below the freezing point temperature
(b) Dehumidifier coil surface temperature is below the dew point temperature but above the freezing point temperature
(c) Dehumidifier coil surface temperature is below the dew point temperature and the freezing point temperature
(d) Dehumidifier coil surface temperature is above the dew point temperature and the freezing point temperature

72. Ans. (b)

**Heating and humidification**

73. In summer air-conditioning, the conditioned air passing through the space undergoes a process of [IAS-1998]
(a) sensible cooling           (b) sensible heating
(c) cooling and dehumidification (d) heating and humidification

73. Ans. (d)

74. The process in a hot water spray washer maintained at a temperature of 40°C, through which unsaturated air at 10°C dry bulb temperature and 50% relative humidity passes, is [IAS-1997]
(a) sensible heating           (b) humidification
(c) heating and humidification (d) heating and dehumidification

74. Ans. (c)
Water at 42°C is sprayed into a stream of air at atmospheric pressure, dry bulb temperature of 40°C and a wet bulb temperature of 20°C. The air leaving the spray humidifier is not saturated. Which of the following statements is true? 

(a) Air gets cooled and humidified  
(b) air gets heated and humidified  
(c) Air gets heated and dehumidified  
(d) Air gets cooled and dehumidified

Ans. (b)

\[
\text{Here, } t_{\text{DBT}} = 40^\circ, \quad t_{\text{WBT}} = 20^\circ \\
\text{Water sprayed at temperature } = 42^\circ
\]

Since, \( t_{\text{water spray}} > t_{\text{DBT}} \) so heating and humidification.

**Cooling and dehumidification**

Air at 35°C DBT and 25°C dew point temperature passes through the water shower whose temperature is maintained at 20°C. What is the process involved?

(a) Cooling and humidification  
(b) Sensible cooling  
(c) Cooling and dehumidification  
(d) Heating and humidification

Ans. (c) As temp of shower (20°C) is below DBT (35°C) sensible cooling will occur. 

As temp of the shower (20°C) is below Dew point temp (25°C) some moisture of will condensed and form water droplets i.e. dehumidification.

If air is passed through a solid chemical absorbent, the psychometric process followed is

(a) heating and dehumidification with the bulb temperature remaining fairly constant  
(b) cooling and dehumidification  
(c) dehumidification with sharp rise in wet bulb temperature  
(d) dehumidification at constant dry bulb temperature.

Ans. (a)

It is desired to condition the outside air from 70% RH and 45°C dry bulb to 50% RH and 25°C dry bulb room condition. The practical arrangement would be

(a) cooling and dehumidification  
(b) dehumidification and pure sensible cooling,  
(c) cooling and humidification  
(d) dehumidification

Ans. (a)

For the following "Matching" exercise, choose the correct one from among the alternatives

A, B, C and D

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Marine Diesel Engine</td>
<td>(A) Two stroke engine</td>
</tr>
<tr>
<td>2. Air conditioning</td>
<td>(B) Four stroke engine</td>
</tr>
<tr>
<td>3. Steam Power Plant</td>
<td>(C) Rotary engine</td>
</tr>
<tr>
<td>4. Gas Turbine Power Plant</td>
<td>(D) Cooling and dehumidification</td>
</tr>
<tr>
<td></td>
<td>(E) Cooling tower</td>
</tr>
<tr>
<td></td>
<td>(F) Brayton cycle</td>
</tr>
<tr>
<td></td>
<td>(G) Rankine cycle</td>
</tr>
</tbody>
</table>

Ans. [GATE-2000]
80. For cooling and dehumidifying of unsaturated moist air, it must be passed over a coil at a temperature
(a) of adiabatic saturation of incoming stream
(b) which is lower than the dew point of incoming stream
(c) which lies between dry bulb and wet bulb temperature
(d) which lies between wet bulb and dew point temperature of incoming stream
80. Ans. (b)

81. To cool and dehumidify a stream of moist air, it must be passed over the coil at a temperature
(a) which lies between the dry bulb and wet bulb temperatures of the incoming stream
(b) which lies between the wet bulb and dew point temperature of the incoming stream
(c) which is lower than the dew point temperature of the incoming stream
(d) of adiabatic saturation of incoming steam
81. Ans. (c)

**Cooling and humidification**

82. Assertion (A): During cooling with humidification dew point decreases.
Reason (R): The process results in increased specific humidity.
82. Ans. (d)

83. A cooling coil with a bypass factor of 0.1 and apparatus dew point (adp) of 12°C comes in contact with air having a dry-bulb temperature of 38°C and dew point of 9°C. Over the cooling coil, the air would undergo
(a) sensible cooling
(b) cooling and humidification
(c) cooling and dehumidification
(d) adiabatic saturation
83. Ans. (b) Apparatus due point = 12°C
∴ minimum temperature expected = 12 × (1 – 0.1) = 10.8°C
So the process is cooling and humidification as 9°C is lower than 10.8°C

84. If air at dry-bulb temperature of 35°C and dew point temperature of 20°C passes through a cooling coil which is maintained at 25°C, then the process would be
(a) sensible cooling
(b) cooling and humidification
(c) cooling and dehumidification
(d) cooling at constant wet bulb temperature
84. Ans. (c)

85. When the air is passed through an insulated chamber having sprays of water maintained at a temperature higher than the dew point temperature of entering air but lower than its dry bulb temperature, then the air is said to be
(a) cooled and humidified
(b) cooled and dehumidified
(c) heated and humidified
(d) heated and dehumidified

---

**Table:**

<table>
<thead>
<tr>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-B</td>
<td>1-C</td>
<td>1-C</td>
<td>1-A</td>
</tr>
<tr>
<td>2-E</td>
<td>2-F</td>
<td>2-F</td>
<td>2-D</td>
</tr>
<tr>
<td>3-F</td>
<td>3-E</td>
<td>3-G</td>
<td>3-G</td>
</tr>
<tr>
<td>4-H</td>
<td>4-G</td>
<td>4-E</td>
<td>4-F</td>
</tr>
</tbody>
</table>

79. Ans. (d)
85. Ans. (a) When air is passed through spray of water at temperature higher than dew point temperature of entering air and lower than its dry bulb temperature, then air is cooled and humidified.

86. In order to cool and dehumidify a stream of moist air, it must be passed over a coil at a temperature
(a) which lies between the dry bulb and wet bulb temperatures of the incoming stream
(b) which lies between the wet bulb and dew point temperatures of the incoming stream
(c) which is lower than the dew point temperature of the incoming stream
(d) of adiabatic saturation of incoming stream
86. Ans. (c)

Heating and dehumidification

Sensible heat factor (SHF)

87. What is the sensible heat factor during the heating and humidification process equal to?
(a) $\frac{H_1+H_2}{H_3-H_1}$  
(b) $\frac{H_2-H_1}{H_3-H_1}$  
(c) $\frac{H_1+H_2}{H_1-H_2}$  
(d) $\frac{H_3+H_1}{H_2-H_1}$

Where, $H_1$ = Total heat of air entering the heating coil
$H_2$ = Total heat of air leaving the heating coil
$H_3$ = Total heat of air at the end of the humidification
87. Ans. (d)

88. The latent heat load in an auditorium is 25% of the sensible heat load. The value of sensible heat factor (SHF) is equal to
(a) 0.25  
(b) 0.5  
(c) 0.8  
(d) 1.0
88. Ans. (c)

89. In a psychrometric process, the sensible heat added is 30 kJ/sec and the latent heat added is 20 kJ/sec. The sensible heat factor for the process will be
(a) 0.3  
(b) 0.6  
(c) 0.67  
(d) 1.5
89. Ans. (b)

90. In an air-conditioning process, 5kJ/min heat is extracted from a room. If the sensible heat factor is 0.8, then the latent heat extracted will be
(a) 4 kJ/min  
(b) 2 kJ/min  
(c) 1 kJ/min  
(d) 0.25 kJ/min
90. Ans. (c)

92. In an auditorium, the heat generated due to the occupants and the electric lights and other equipments is 100 kW. The rate of generation of excess moisture is 60kg/hr. If an air-conditioner is supplying conditioned air to the auditorium at the rate of 500 m$^3$/min, then the sensible heat factor (SHF) for the auditorium is
(a) 0.27  
(b) 0.40  
(c) 0.73  
(d) 0.95
92. Ans. (c)
Psychometric Processes in Air Conditioning Equipment

Bypass factor

93. Atmospheric air at dry bulb temperature of 15°C enters a heating coil whose surface temperature is maintained at 40°C. The air leaves the heating coil at 25°C. What will be the by-pass factor of the heating coil? [IES-2004]
(a) 0.376 (b) 0.4 (c) 0.6 (d) 0.67
93. Ans. (b) BPF = 1 - \frac{\text{Actual temp. increased}}{\text{Max possible temp. increased}} = 1 - \frac{40 - 25}{40 - 15} = 1 - 0.6 = 0.4

94. In order to have a low bypass factor of a cooling coil, the fin spacing and the number of tube rows should be: [IES-2005]
(a) Wide apart and high, respectively (b) Wide apart and low, respectively (c) Close and high, respectively (d) Close and low, respectively
94. Ans. (c)

95. Air is 20°C dry bulb temperature and 40% relative humidity is heated upon 40°C using an electric heater, whose surface temperature is maintained uniformly at 45°C. The bypass factor of the heater is [IES-1999]
(a) 0.20 (b) 0.25 (c) 0.88 (d) 1
95. Ans. (a) Bypass factor = \frac{t_3 - t_2}{t_1 - t_i} = \frac{45 - 40}{45 - 20} = 0.2

96. For low bypass factor a cooling coil, the fin spacing and the number of tube rows will be respectively [IES-1998]
(a) high and high (b) high and low (c) low and high (d) low and low
96. Ans. (d) Low bypass factor is indication of poor heat transfer. For better transfer, no. of coils should be more and fin spacing should be higher

97. The atmosphere air at dry bulb temperature of 15°C enters a heating coil maintained at 40°C. The air leaves the heating coil at 25°C. The bypass factor of the heating coil is (a) 0.375 (b) 0.4 (c) 0.6 (d) 0.67 [IES-1994]
97. Ans. (d) Bypass factor of heating coil = \frac{40 - 25}{40 - 15} = 0.67

98. In the case of sensible cooling of air, the coil efficiency is given by (BPF = Bypass factor)
(a) BPF-1 (b) 1-BPF (c) BPF (d) 1 + BPF [IES-1993]
98. Ans. (b) Coil efficiency in the sensible cooling is = 1 - BPF

Reason (R): Air gets more time to contact the cooling coil at lower face velocity.
99. Ans. (b)
100. The condition of air for a cooling and dehumidification system is given by the point A at intake, B at discharge as marked on a psychometric chart. It C is the apparatus dew point, the bypass factor is given by 

\[
\frac{CA}{AB} \quad \frac{CA}{BC} \quad \frac{BC}{AB} \quad \frac{BC}{CA}
\]

[IAS-1996]

100. Ans. (d)

101. Consider the following statements
1. Low value of the bypass factor for an air-conditioning equipment signifies higher performance of the equipment [IAS 1994]
2. Bypass factor for an air-conditioning equipment signifies the fraction of ambient air mixed with the air to be conditioned.
3. Bypass factor for an air-conditioning equipment signifies the fraction of the air to be conditioned coming in contact with the conditioning surface.

Of these statements:
(a) I and III are correct
(b) I and II are correct
(c) III alone is correct
(d) II alone is correct

101. Ans. (b)

102. The by-pass factor of single cooling coil in an air-conditioner is 0.7. The by-pass factor, if three such cooling coils with the same apparatus dew point are kept one behind the other will be

(a) 0.210  
(b) 0.292  
(c) 0.343  
(d) 0.412  [IES-2001]

102. Ans. (c)

103. By pass factor for a cooling coil [IES-1992]
(a) increases with increase in velocity of air passing through it
(b) decrease with increase in velocity of air passing through it
(c) remains unchanged with increase in velocity of air passing through it
(d) may increase or decrease with increase in velocity of air passing through it depending upon the condition of air entering.

103. Ans. (a)

Air Washer

104. Consider the following statements: [IES-2006]
Air washer can work as
1. Humidifier only  
2. Dehumidifier only  
3. Filter only
Which of the statements given above is/are correct?
(a) Only 1  
(b) Only 2 and 3  
(c) Only 1 and 3  
(d) 1, 2 and 3

104. Ans. (c)

105. Air at dry bulb temperature of 35°C and dew point temperature of 25°C passes through an air washer whose temperature is maintained at 20°C. What is the nature of the process involved? [IES-2005]
(a) Cooling and humidification  
(b) Sensible cooling
105. Ans. (d)

106. Air (at atmospheric pressure) at a dry bulb temperature of 40°C and wet bulb temperature of 20°C is humidified in an air washer operating with continuous water recirculation. The wet bulb depression (i.e., the difference between the dry and wet bulb temperatures) at the exit is 25% of that at the inlet. The dry bulb temperature at the exit of the air washer is closest to [GATE-2008]
(A) 100°C (B) 20°C (C) 25°C (D) 30°C

106. Ans. (C)

107. In a spray washing system, if the temperature of water is higher than the dry bulb temperature of entering air, then the air is [IES-1993]
(a) heated and dehumidified (b) heated and humidified (c) cooled and humidified (d) cooled and dehumidified
107. Ans. (b)

108. Two streams moist air ‘1’ and ‘2’ mix together stream of unsaturated air ‘3’. Let ‘m’ denote the rate of total mass flow of moist air, ‘m_\omega’ denote the rate of mass flow of associated water vapour, ‘\omega’ denote the specific humidity and ‘t’ the temperature of a stream. Then ‘t_3’ the temperature of stream ‘3’ will be [IAS-1995]
(a) \[ \frac{(m_1 - m_{\omega_2})\omega_1 t_1 + (m_2 - m_{\omega_2})\omega_2 t_2}{m_3 - m_{\omega_3}} \] (b) \[ \frac{(m_1 - m_{\omega_2})t_1 + (m_2 - m_{\omega_2})t_2}{m_3 - m_{\omega_3}} \]
(c) \[ \frac{\omega_1 t_1 + \omega_2 t_2}{\omega_3} \] (d) \[ \frac{m_1 \omega_1 t_1 + m_2 \omega_2 t_2}{m_3 \omega_3} \]
108. Ans. (b)

Air Conditioning

109. For an air-conditioned space, RTH = 100 kW, RSHF = 0.75, volume flow rate = 100 m³/min, and indoor design specific humidity is 0.01 kg/kg of dry air. What is the specific humidity of the supply air? [IES-2005]
(a) 0.010 (b) 0.0075 (c) 0.005 (d) 0.0025

109. Ans. (c)

\[ \omega_{\text{min}} = \frac{\text{RLH}}{50(\omega_1 - \omega_{\text{ADH}})} \quad \text{or} \quad 100 = \frac{25}{50(\omega_1 - 0.01)} \quad \text{or} \quad (\omega_1 - 0.01) = 0.005 \]

\[ \text{RSHF} = \frac{\text{RSH}}{\text{RTH}} = \frac{\text{RSH}}{\text{RSH} + \text{RLH}} \]

110. Consider the following statements: [IAS-2000]
1. If air is heated in a closed chamber, its dew point will increase
2. As relative humidity decreases, the difference between the wet-bulb temperature and dew point will increase
3. In spray humidification process, the enthalpy of air will decrease
4. The dew-point temperature is always an indication of moisture content of the air
Which of these statements are correct?
(a) 1 and 2 (b) 2 and 4 (c) 1 and 3 (d) 3 and 4
110. Ans. (b)
1. As no moisture is added so no change in dew point.
2. 
\[(t_w1 - t_d1) < (t_w2 - t_d2)\]

3. By energy balance it increases not decreases because it added water's enthalpy 
\[h_2 = h_1 + (\omega_2 - \omega_1)h_1\]

4. See above graph
So 2 & 4 are correct

111. Air-conditioning has to be done for a hall whose RSH = 50 kW and RLH = 50 kW.
There are no other sources of heat addition or leakages. What is the value of the RSHF?
(a) 0.25 (b) 0.5 (c) 0.75 (d) 1.00  [IES-2005]
111. Ans. (b)

\[
RSHF = \frac{RSH}{RSH + RLH} = \frac{50}{50 + 50} = 0.5
\]

112. Consider the following statements:  [IAS-2007]
When a GSHF line is extended, it may strike the saturation curve at a point. This point is called
1. effective surface temperature.  2. air saturation temperature.
3. water boiling temperature.  4. apparatus dew point.
Which of the statements given above are correct?
(a) 1 and 2 (b) 1 and 4 (c) 2 and 3 (d) 3 and 4
112. Ans. (b)

113. In the case of a cooling coil with non-zero bypass factor, the apparatus, dew point temperature lies at the intersection point of  [IAS-1997]
(a) room DB line with the saturation curve (b) RSHF and GSHF lines
(c) RSHF and ESHF lines (d) GSHF line with the saturation curve
113. Ans. (d)

114. The state of air supplied by a cooling coil with a by-pass factor X lies on the psychometric chart at the  [IAS-1998]
(a) intersection of RSHF line with saturation curve (b) intersection of GSHF line with saturation curve
(c) point which divides RSHF line in proportion to X and (1 - X) (d) point which divides ESHF line in proportion to X and (1-X)
114. Ans. (d)

115. Fresh air intake (air change per hour) recommended for ventilation purposes in the air-conditioning system of an office building is  [IES-1997]
115. Ans. (c)

116. In aircraft, air refrigeration cycle is used because of

(a) low unit weight per tonne of refrigeration
(b) high heat transfer rate.
(c) lower temperature at high-altitudes
(d) higher coefficient of performance.

116. Ans. (a)

117. Consider the following statements related to all-air air-conditioning system:

1. All air system uses air as heating or cooling fluid.
2. When hot air is circulated through rooms, dehumidification is necessary to control relative humidity.
3. Return air ducts are required for recirculation.

Which of the statements given above are correct?

(a) 1, 2 and 3
(b) 1 and 2 only
(c) 1 and 3 only
(d) 2 and 3 only

117. Ans. (c)

118. Assertion (A): Dehumidification and humidification respectively are needed in winter and summer air-conditioning.
Reason (R): In winter, the air is to be heated and in summer, the air is to be cooled and moisture control is necessary to maintain the relative humidity within limits.

118. Ans. (a) Both A and R are true and R provides correct explanation for A.

119. Moist air at a pressure of 100 kPa is compressed to 500 kPa and then cooled to 35°C in an after cooler. The air at the entry to the after cooler is unsaturated and becomes just saturated at the exit of the after cooler. The saturation pressure of water at 35°C is 5.628 kPa. The partial pressure of water vapour (in kPa) in the moist air entering the compressor is closest to

(A) 0.25
(B) 0.5
(C) 0.75
(D) 1

119. Ans. (B) Volume change is one fifth and water vapour just compressed to one fifth volume so unsaturated vapour pressure = \( \frac{5.628}{5} \approx 1.13 kPa \)
Answers with Explanation (Objective)
Air refrigeration system

Objective Questions (IES, IAS, GATE)

Boot-strap

Simple evaporative

Regenerative

Boot-strap evaporative
1. Which is the most suitable type of air refrigeration system for supersonic planes with Mach Number 3 or above? [IES-2005]
   (a) Boot-strap        (b) Simple evaporative
   (c) Regenerative      (d) Boot-strap evaporative
   1. Ans. (d) Actually for this use Reduced Ambient system of refrigeration.

Comfort
2. In a system: Metabolic rate = M, work done by man = W, rate of convective, radiative and evaporative heat losses = Q and rate of heat storage = S. Then heat exchange between man and his environment is given by [IES-2002]
   (a) M + W = Q + S   (b) M - W = Q - S
   (c) M + W = Q - S   (d) M - W = Q + S
   2. Ans. (d)

3. A human body feels comfortable when the heat produced by the metabolism of human body is equal to [IES-2006]
   (a) Heat dissipated to the surroundings   (b) Heat stored in the human body
   (c) Sum of (a) and (b)            (d) Difference of (a) and (b)
   3. Ans. (c)

4. A human body feels comfortable when the heat produced by the metabolism of human body is equal to the [IES-1993]
   (a) heat dissipated to the surroundings       (b) heat stored in the human body
   (c) sum of (a) and (b)                      (d) difference of (a) and (b)
   4. Ans. (a)

5. A passive method to keep the house comfortably warm by solar conditioning in cold climatic condition is to paint the: [IES-2005]
   (a) Eastern wall of the house by black paint on its outer side
   (b) Eastern wall of the house by back paints on its inner side
   (c) Southern wall of the house by black paint on its outer side
   (d) Southern wall of the house by black paint on its inner side
   5. Ans. (b)
6. On which factor(s), does the heat lost by the human body in the process of radiation depend?  
(a) Temperature only   (b) Temperature and air motion   (c) Temperature and relative humidity   (d) Relative humidity and air motion  
6. Ans. (a)  

7. Which of the following are normally desired comfort conditions in an air-conditioning system?  
(a) 25°C DBT and 50% RH   (b) 22°C DBT and 90% RH   (c) 15°C DBT and 75% RH   (d) 15°C DBT and 40% RH  
7. Ans. (a)  

8. The desirable air velocity in the occupied zone for comfort for summer air-conditioners is in the range of  
(a) 6 - 7 m/minute   (b) 4 - 5 m/minute   (c) 2 - 3 m/minute   (d) 0.5 - 1.5 m/minute  
8. Ans. (d)  

9. A human body feels comfortable when the heat produced due to metabolism of human body is equal to the  
(a) heat dissipated to the surroundings   (b) heat stored in human body   (c) difference between heat dissipated to the surroundings and heat stored in human body   (d) sum of heat dissipated to the surroundings and heat stored in human body  
9. Ans. (a) A human body feels comfortable when the heat produced due to metabolism of human body gets equal to the heat dissipated to the surroundings.  

10. The reason for a person feeling more comfortable on a warm day if seated in front of an electric fan is that the  
(a) metabolic heat production is reduced   (b) body loses more heat by convection and evaporation   (c) body loses more heat by radiation   (d) body loses more heat by evaporation and radiation  
10. Ans. (b)  

11. On a summer day, a scooter rider feels more comfortable while on the move than while at a stop light because  
(a) an object in motion captures less solar radiation.   (b) air is transparent to radiation and hence it is cooler than the body.   (c) more heat is lost by convection and radiation while in motion   (d) Air has a low specific heat and hence it is cooler.  
11. Ans. (a) A body in motion captures less solar radiation.  

12. Assertion (A): The actual inside design temperatures selected in comfort air-conditioning are not necessarily those conditions of optimum comfort.  
Reason (R): The length and type of occupancy, the outside design conditions and economic factors affect the choice.  
12. Ans. (a)  

13. In room air-conditioning for comfort, the supply air in summer should be at  
(a) the same temperature as that of the room   (b) 5 to 10°C below the room temperature  
13. Ans. (b)
13. Ans. (b)

14. What are the general comfort conditions in an air-conditioning system?
(a) 20°C DBT, 80% RH  (b) 24°C DBT, 60% RH  \[\text{IES-2006}\]
(c) 25°C DBT, 40% RH  (d) 25°C DBT, 100% RH
14. Ans. (b)

15. Which of the following statements are correct? \[\text{IES-1994}\]
1. The human body can lose heat even if its temperature is less than the atmospheric temperature.
2. Relative humidity can be increased by cooling and dehumidification.
3. Warm air increases the rate of radiation of heat from the human body.
4. Increase in air movement increases the evaporation from the human body.
Codes: (a) 1 and 4  (b) 2 and 4  (c) 1 and 3  (d) 2 and 3
15. Ans. (a)

16. The difference between the comfort airconditioning and industrial airconditioning lies in the \[\text{IAS-1998}\]
(a) equipment used  (b) process adopted
(c) indoor requirements  (d) ambient conditions
16. Ans. (c)

**Effective temperature**

17. Effective temperature depends on dry bulb temperature, and \[\text{IES-2006}\]
(a) Wet bulb temperature only  (b) Relative humidity
(c) Specific humidity  (d) Wet bulb temperature and air motion
17. Ans. (d)

18. Dry bulb temperature and wet bulb temperature is 25°C each, and velocity of air passing over human body is 6 m/min. If velocity increases to 20 m/min, then which one of the following is correct? \[\text{IES-2006}\]
(a) The effective temperature decreases
(b) The effective temperature remains the same
(c) The effective temperature increases
(d) The change in effective temperature cannot be estimated with the given information
18. Ans. (a) Any activity which increase human comfort will reduce effective temperature.

Alternatively: Rydberg and Norback equation gives us difference
\[\Delta t = (t – 24.4) - 0.1276 (C – 9.1)\]
t = local temperature, °C; C = local velocity m.p.m
if t is constant and C increases from 6 to 20 m/min
\[\Delta t = - 0.1276 (6 – 20) = - 1.8 °C\]

19. Which one of the following statements is correct? \[\text{IES-2005}\]
The optimum effective temperature for human comfort is:
(a) higher in winter than that in summer  (b) lower in winter than that in summer
(c) same in winter and summer  (d) not dependent on season
19. Ans. (b)
20. Which one of the following statements is correct? 
(a) Effective temperature is the index which the correlates combined effects of air dry bulb temperature, air humidity and air movement upon human comfort 
(b) The value of effective temperature in winter and summer should be same for human comfort 
(c) Effective temperature and wet bulb temperature are one and the same 
(d) The value of effective temperature should be higher in winter than In summer for comfort 
20. Ans. (a) 

21. Upon which of the following factors does the effective temperature for human comfort depend? 
1. Dry bulb temperature  
2. Humidity ratio  
3. Air velocity  
4. Mean radiation temperature 
Select the correct answer from the codes given below: 
(a) 1 and 2   (b) 1, 3 and 4   (c) 2, 3 and 4   (d) 1, 2, 3 and 4 
21. Ans. (d) 

22. Assertion (A): Effective temperature, an index of comfort, is defined as that temperature of saturated air at which one would experience the same feeling of comfort as experienced in the actual environment. 
Reason (R): Comfort does not depend on humidity and air velocity. 
22. Ans. (c) 

23. Consider the following parameters: 
1. Dry-bulb temperature  
2. Humidity ratio  
3. Air velocity  
4. Solar radiation intensity 
Which of these parameters are taken into account for determining effective temperature for human comfort? 
(a) 1 and 2   (b) 1 and 4   (c) 2, 3 and 4   (d) 1, 2 and 3 
23. Ans. (d) 

24. The effective temperature is a measure of the combined effects of 
(a) dry bulb temperature and relative humidity 
(b) dry bulb temperature and air motion 
(c) wet bulb temperature and air motion  
(d) dry bulb temperature, relative humidity and air motion 
24. Ans. (d) The effective temperature is the combined effect of dry bulb temperature, relative humidity and air motion. 

25. Effective temperature is that temperature of saturated air which gives the same degree of comfort as the air at given 
(a) DBT, WBT and incidental solar radiation 
(b) WBT, incidental solar radiation and air flow rate 
(c) DBT, sol-air temperature and air flow rate   
(d) DBT, WBT and air flow rate 
25. Ans. (d) 

26. Which one of the following statements is true for effective temperature, ET? 
(a) ET increases with increase in level of activity and it decreases with increase in air velocity 
26. Ans. (a)
(b) ET decreases with increase in level of activity and it increases with increase in air velocity.
(c) ET increases with increase in level of activity and it increases with increase in air velocity.
(d) ET decreases with increase in level of activity and decreases with increase in air velocity.
26. Ans. (c) Rule: Any activity which reduces comfort will increase ET.

27. Consider the following statements: Effective temperature is NOT a true comfort index because L discomfort may be experienced at extremely high or low humilities. 2. the radiation effect of surrounding surfaces has not been taken into account. 3. it presumes the absence of drafts.
Of these statements:
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct
(c) 1 and 3 are correct (d) 2 and 3 are correct
27. Ans. (b)

28. Consider the following statements: Effective temperature
1. Is a measure of the sensation of warmth or coldness. [IAS-1996]
2. Is the uniform temperature of an imaginary enclosure with which man will exchange the same dry heat by radiation and connection as in the actual environment.
3. Combines the effects of dry bulb temperature, wet bulb temperature and air movement.
Of these statements:
(a) 1 and 2 are correct (b) 1 and 2 are correct (c) 2 and 3 are correct (d) 1 and 3 are correct
28. Ans. (a)

29. A room air is at a DBT of $T_r$ and relative humidity $\phi_r$. The effective temperature of the room is
(a) the temperature at which the room air is saturated but gives the same feeling of comfort as the actual state of the room air [IAS 1994]
(b) the temperature at which the room air is at 50% relative humidity but gives the same feeling of comfort as the actual state of the room air
(c) the temperature at which the room air is completely dry but gives the same feeling of comfort as the actual state of the room air.
(d) none of the above
29. Ans. (a)

Load calculation

30. The heat load from the occupants in air-conditioning load calculation is a source of:
(a) Sensible heat only (b) Latent heat only [IES-2006]
(c) Both sensible and latent heat (d) None of the above
30. Ans. (c)
31. An air-conditioned room of volume 10 m$^3$ has infiltration of air equivalent to 3 air changes per hour. Density of air is 1.2 kg/m$^3$, specific heat $c_p$ is 1 kJ/kg K and temperature difference between room and ambient air is 20 K. What is the sensible heat load due to infiltrated air? 
(a) 60 kJ/hour   (b) 12 kJ/hour   (c) 0.45 kW   (d) 0.2 kW

31. Ans. (d) 

\[ Q = m c_p \Delta t = \left( \frac{10 \times 3}{3600} \times 1.2 \right) \times 1 \times 20 = 0.2 \text{ kW} \]

32. In an air-conditioning plant the refrigeration load on the coil is 100 TR. The mass and enthalpy of air leaving the coil are 420 kg/minute and 40 kJ/kg respectively. What will be the enthalpy of the air at the inlet to the coil under these conditions? 
(3) 80 kJ/kg   (b) 90 kJ/kg   (c) 100 kJ/kg   (d) 102.5 kJ/kg

32. Ans. (b) 

\[ \Delta h = \frac{Q}{m} = \frac{100 \times 210 \text{kJ/min}}{420 \text{ kg/min}} = 90 \text{ kJ/kg} \]

33. Moist air enters the cooling coil with mass flow rate of 10 kgda/s at dry bulb temperature of 30°C and humidity ratio of 0.017 kgw/kgda. It leaves the cooling coil at dry bulb temperature of 16°C and humidity ratio of 0.008 kgw/kgda. If specific heat of humid air is 1.02 kJ/kgda-K and latent heat of water vapour is 2500 kJ/kgw. The sensible and latent heat transfer of cooling coil are, respectively 
(a) 140 kW and 25000 kW   (b) 142.8 kW and 2.25 kW   (c) 142.8 kW and 225 kW   (d) 225 kW and 142.8 kW

33. Ans. (c) We know that humid specific heat, $C_p = C_{pd} + \omega C_{pw} = 1.02 \text{ KJ/kgda.K}$

Therefore, Sensible heat load (SHL) = $m \left( C_p \Delta T_{db} \right) = 10 \times 1.02 \times (30 - 16) = 142.8kW$

and Latent heat load (LHL) = $m \left( \omega \Delta h_{fg} \right) = 10 \times (0.017 - 0.008) \times 2500 = 225kW$

34. Atmospheric air at a flow rate of 3 kg/s (on dry basis) enters a cooling and dehumidifying coil with an enthalpy of 85 kJ/kg of dry air and a humidity ratio of 19 grams/kg of dry air. The air leaves the coil with an enthalpy of 43 kJ/kg of dry air and a humidity ratio of 8 grams/kg of dry air. If the condensate water leaves the coil with an enthalpy of 67 kJ/kg, the required cooling capacity of the coil in kW is 
(a) 75.0   (b) 123.8   (c) 128.2   (d) 159.0

34. Ans. (b) 

35. An air-conditioned room has length, width and height of 20 m, 30 m and 4 m respectively. The infiltration is assumed to be one air change. The outdoor and indoor dry bulb temperatures are 40°C and 25°C respectively. The sensible heat load due to infiltration is 
(a) 734 kW   (b) 12.24 kW   (c) 0.204 kW   (d) 10 kW

35. Ans. (d)
35. Ans (b) Infiltration ‘1’ air change per hour, i.e., \((cmm) = \frac{20 \times 30 \times 4}{60} m^3/min\)

\[
Q_s = \frac{1.2 \times (cmm) \times C_p \times (\Delta t)}{60} = \frac{1.2 \times \left(\frac{20 \times 30 \times 4}{60}\right) \times 1.02 \times (40 - 25)}{60} kW = 12.24 kW
\]

36. For an office building the outdoor design conditions are 45°C dbt and humidity ratio of 0.015. The indoor design conditions are 25°C dbt and 0.01 humidity ratio. The supply air state is 15°C dbt and 0.007 humidity ratio. If the supply air flow rate is 1000 m³/ min and fresh air flow rate is m³/ min, room sensible and room latent heat loads are, respectively,

- (a) 408 kW and 400 kW
- (b) 408 kW and 150 kW
- (c) 204 kW and 400 kW
- (d) 204 kW and 150 kW

36. Ans. (d)

37. For an air-conditioning system, the outdoor and indoor design dry bulb temperatures are 45°C and 25°C respectively. The space to be air-conditioned is 20 m x 30 m x 5 m and infiltration is estimated to be one air change. If the density and specific heat of air are 1.2 (kg of dry air)/m³ and 1.02 kJ/(kg of dry air)°C, then the sensible heat load due to infiltration is, nearly

- (a) 122.4 kW
- (b) 61.2 kW
- (c) 12.24 kW
- (d) 2004 kW

37. Ans. (d)

38. For an air-conditioned space, RTH = 100 kW; RSHF = 0.75, volume flow rate is equal to 100 m³/minute and indoor design specific humidity is 0.01 kg/(kg of dry air). The specific humidity of supply air is

- (a) 0.010
- (b) 0.0075
- (c) 0.005
- (d) 0.0025

38. Ans. (c)

39. Consider the following statements:

1. The recommended outside air required per person for an auditorium is approximately 0.25 m³/min.
2. Outside air for ventilation purposes causes sensible heat load and also latent heat load.
3. The sensible heat factor for an auditorium is generally kept as 0.7

Which of these statements are correct?

- (a) 1 and 2
- (b) 2 and 3
- (c) 1 and 3
- (d) 1, 2 and 3

39. Ans. (c)

40. An air-conditioned room of volume 10 m³, has infiltration of air equivalent to 3 air changes. Density of air is 1.2 kg/m³, specific heat \(C_p\) is 1 kJ/kg-K and temperature difference between room and ambient air is 20 K. The sensible heat load due to infiltrated air is

- (a) 60 kJ/hr
- (b) 12 kJ/hr
- (c) 6 kW
- (d) 0.2 kW

40. Ans. (d)

41. The sensible heat factor of a room is given by \(S.H.L = \text{Sensible heat load and } L.H.L. = \text{Latent heat load}\)
41. Ans. (d) \( \text{SHF} = \frac{\text{S.H.L}}{\text{S.H.L} + \text{L.H.L}} \)

42. In air-conditioning design for summer months, the condition inside a factory where heavy work is performed as compared to a factory in which light work is performed should have
(a) lower dry bulb temperature and lower relative humidity
(b) lower dry bulb temperature and higher relative humidity
(c) lower dry bulb temperature and same relative humidity
(d) same dry bulb temperature and same relative humidity

42. Ans. (d) Air conditioning parameters are same for all conditions of loading. Air conditioning capacity has to be designed for the heat load to maintain the parameters

43. Two summer air-conditioning systems with non-zero by pass factor are proposed for a room with a known sensible and latent heat load. System A operates with ventilation but system B operates without ventilation. Then the
(a) bypass factor of system A must be less than the bypass factor of system B
(b) bypass factor of system A must be more than the bypass factor of system B
(c) apparatus dew point for system A must be lower than the apparatus dew point for system B
(d) apparatus dew point for system A must be higher than the apparatus dew point for system B.

43. Ans. (c)

44. Consider the following factors:
1. Wind velocity
2. Type of activity
3. Indoor design conditions
4. Door openings

Occupancy load in cooling load calculations depends upon
(a) 1 and 2
(b) 1 and 3
(c) 1 and 4
(d) 2 and 3.

44. Ans. (d) Occupancy load in cooling load calculation depend upon type of activity and indoor design conditions.

**Solar refrigeration**

45. What is Sol-air temperature?

(a) It is equal to the sum of outdoor air temperature, and absorbed total radiation divided by outer surface convective heat transfer coefficient
(b) It is equal to the absorbed total radiation divided by convective heat transfer coefficient at outer surface
(c) It is equal to the total incident radiation divided by convective heat transfer coefficient at outer surface
(d) It is equal to the sum of indoor air temperature and absorbed total radiation divided by convective heat transfer coefficient at outer surface

45. Ans. (a) sol-air temperature \( t_o = t_o + \frac{\alpha I}{h_o} \)

Rate of heat transfer from outside to wall is \( q_o \). \( q_o = h_o(t_o - t_s) + \alpha I = h_o(t_o - t_s) \)

For heat transfer through building structure the sol-air temperature is used instead of conduction and solar radiation separately.
46. A thin flat plate 2m by 2m is hanging freely in air. The temperature of the surroundings is 25°C. Solar radiation is falling on one side of the plate at the rate of 500 W/m². The temperature of the plate will remain constant at 30°C, if the convective heat transfer coefficient (in W/m²°C) is
(a) 25   (b) 50   (c) 100   (d) 200  
IES-1993

46. Ans. (a) Heat transfer by convection
\[ Q = hA\Delta t \]
or \[ 500 \times (2 \times 2) = h \times (2 \times 2) \times (30 - 25) \text{ or } h = 100 \text{ W/m}^2\text{°C} \]

47. Assertion (A): Solar Radiation is mainly scattered or transmitted but not absorbed by the atmosphere.
Reason (R): Absorptivity of atmosphere is low.
IES-1992

47. Ans. (a)

48. A thin flat plate 2 m x 2 m is hanging freely in air. The temperature of the surroundings is 25°C. Solar radiation is falling on one side of the plate at the rate of 500 W/m². What should be the convective heat transfer coefficient in W/m²°C if the temperature of the plate is to remain constant at 30°C?
(a) 25   (b) 50   (c) 100   (d) 200  
IES-2005

48. Ans. (b) Heat absorbed = heat dissipated or
\[ G.A = h \times (2A) \times \Delta t \]
or \[ 500 = h \times 2 \times (30 - 25) \text{ or } h = \frac{500}{2 \times 5} = 50 \text{ W/m}^2\text{°C} \]

49.

(a) \[ R_{CO} + R_W + R_{Cl} \]
(b) \[ R_W + R_{CO} + R_{Cl} \]
(c) \[ R_{CO} + R_{Cl} + R_W \]
(d) \[ R_W + R_{Cl} + R_{CO} \]

Solar energy is absorbed by the wall of a building as shown in the above figure. Assuming that the ambient temperature inside and outside are equal and considering steady-state, the equivalent circuit will be as shown in
Symbols: \( R_{CO} = R_{\text{convection, outside}} \), \( R_{Cl} = R_{\text{convection, inside}} \) and \( R_w = R_{\text{Wall}} \)
IES-1998

49. Ans. (a) All resistances are in series.

50. A solar collector receiving solar radiation at the rate of 0.6 kW/m² transforms it to the internal energy of a fluid at an overall efficiency of 50%. The fluid heated to 350 K is used to run a heat engine which rejects heat at 313 K. If the heat engine is to deliver 2.5 kW power, then minimum area of the solar collector required would be
(a) 8.33 m²   (b) 16.66 m²   (c) 39.68 m²   (d) 79.36 m²  
GATE-2004
50. Ans. (d)

Let area be A → heat received (G) = 0.6A kW
and power given to the fluid (Q) = G × ε = 0.6A × 0.5 = 0.3A kW

Maximum efficiency is Carnot Efficiency

\[ \eta = 1 - \frac{313}{350} = 0.10571 \]

Power deliver (W) = Q × η

Or 2.5 = 0.3A × 0.10571 or A = 79.36 m²

51. Assertion (A): In an air-conditioned room, the reflective coating should be on the inside of the window.
Reason (R): Window pane glass is transparent to solar radiation. [IES-1996]

51. Ans. (d) A is false but R is true

**Duct Design**

52. Consider the following statements pertaining to duct design: [IES-2006]

1. Aspect ratio of ducts should be high.
2. In the equal friction, method of design, use of dampers cannot be eliminated by any means.
3. The static regain method is not suitable for long ducts.
4. The velocity reduction method is employed only in simple systems.

Which of the statements given above are correct?
(a) 1 and 2   (b) 3 and 4  (c) 1 and 3   (d) 2 and 4

52. Ans. (b)

53. Which one of the following statements is true for air conditioning duct design?
(a) Static regain method is used, when the duct work is extensive, total pressure drop is low and flow is balanced
(b) Static regain method is used, when the duct work is extensive, total pressure drop is high and flow is unbalanced
(c) Equal friction method is used, when the duct work is extensive, total pressure drop is low and flow is balanced
(d) Equal friction method is used, when duct work is extensive, total pressure drop is low and flow is unbalanced [IES-2001]

53. Ans. (c)

54. If coefficient of contraction at the vena contracta is equal to 0.62, then what will be the dynamic loss coefficient in sudden contraction in air-conditioning duct? [IES-2004]

\[ K = \left( \frac{1}{C_{e} - 1} \right)^2 = \left( \frac{1}{0.62 - 1} \right)^2 = 0.375 \]

54. Ans. (b)

55. Consider the following statements in respect of the contraction and expansion in air conditioning ducts: [IES-2003]

1. Pressure drop is more in contraction than in expansion.
2. Pressure drop is more in expansion than in contraction.
3. Static pressure increases (regain) in expansion.
4. Static pressure increases (regain) in contraction.

Which of these statements are correct?
(a) 1 and 2  (b) 1, 2 and 3  (c) 1 and 3  (d) 2 and 4
55. Ans. (c)

56. Consider the following statements:
The typical air velocities in the ducts of air-conditioning systems are
1. lower in residential buildings as compared to those of public buildings
2. higher in residential buildings as compared to those of public buildings
3. higher in industrial buildings as compared to those of public buildings
4. equal in all types of buildings
Which of these statements is/are correct?
(a) 1 alone   (b) 1 and 3   (c) 2 and 3   (d) 4 alone
56. Ans. (b)

57. Which of the following method(s) is/are adopted in the design of air duct system?
Select the correct answer using the codes given below:  
IES-1998
Codes:
(a) 1 alone   (b) 1 and 2   (c) 2 and 3   (d) 1, 2 and 3
57. Ans. (c)

58. The most commonly used method for the design of duct size is the  
IES-1996
(a) velocity reduction method  (b) equal friction method.
(c) static regain method       (d) dual or double duct method.
58. Ans. (a) The most commonly used method for the design of duct size is the velocity reduction method

59. The equivalent diameter (D) of a circular duct corresponding to a rectangular duct having longer side ‘a’ and shorter side ‘b’, for the same velocity and pressure drop is given by  
IES-1994
(a) \( D = \frac{a+b}{ab} \)  (b) \( D = \frac{ab}{a+b} \)  (c) \( D = \frac{a+b}{2ab} \)  (d) \( D = \frac{2ab}{a+b} \)
59. Ans. (d)

60. Which of the following items related to infiltration of outdoor air in an air-conditioning system, are correctly matched?  
IAS-2007
1. Stack effect    : Height of building
2. Crack length method   : Wind velocity
3. Air change method   : Floor area
4. Door opening    : Occupancy in kitchen
Select the correct answer using the code given below:
(a) 1 and 2   (b) 1 and 3   (c) 1 and 4   (d) 2 and 4
60. Ans. (a)

61. Match List I with List II and select the correct answer using the codes given below the lists:

<table>
<thead>
<tr>
<th>List I (Material)</th>
<th>List II (Purpose/application)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Glass wool</td>
<td>1. Cold storage</td>
</tr>
<tr>
<td>B. Ammonia</td>
<td>2. Domestic refrigerators</td>
</tr>
</tbody>
</table>
61. Ans. (a)

62. Which one of the following statements is correct? [IAS-1995]
(a) The sensible heat gain is due to the difference in humidity
(b) The latent heat gain is due to the temperature difference between the fresh air through unconditioned space in the building adds to the sensible heat gain
(c) The heat gain through the walls of ducts carrying conditioned air through unconditioned space in the building adds to the sensible heat gain
(d) Maximum heat gain to a building occurs through walls

62. Ans. (c)

63. For air-conditioning the operation theatre in a hospital, the percentage of outside air in the air supplied is
(a) zero  (b) 20  (c) 50  (d) 100 [IAS-1995]

63. Ans. (d) It is advisable to recalculate infected air of operation theatre and accordingly % age of outside air is 100%.

Statement for Linked Answer Questions 64 and 65:
An un-insulated air conditioning duct of rectangular cross section 1m x 0.5 m, carrying air at 20°C with a velocity of 10 m/s, is exposed to an ambient of 30°C. Neglect the effect of duct construction material. For air in the range of 20-30°C, data are as follows: thermal conductivity = 0.025W/mK; velocity = 18 µPas; Prandtl number = 0.73; density = 1.2 kg/m³. The laminar flow Nusselt number is 3.4 for constant wall temperature conditions and, for turbulent flow, \( \text{Nu} = 0.023 \, \text{Re}^{0.8} \text{Pr}^{0.8} \)

64. The Reynolds number for the flow is [GATE-2005]
(a) 444  (b) 890  (c) 4.44 \( \times \) 10⁵  (d) 5.33 \( \times \) 10⁵

64. Ans. (c)

65. The heat transfer per metre length of the duct, in watts, is [GATE-2005]
(a) 3.8  (b) 5.3  (c) 89  (d) 769

65. Ans. (d)
\[
\begin{align*}
\text{Nu} &= 0.023 \times (\text{Re})^{0.8} \times (0.73)^{0.33} = 683.72 \\
\text{Nu} &= \frac{\text{h}D}{k} \text{ or } \text{h} = \frac{683.72 \times 0.025}{0.6667} = 25.64 \\
Q &= \text{h}A (t_a - t_0) = 25.64 \times 2 \times (1 + 0.5) \times 1 \times (30 - 20) = 769 \text{ W/m}
\end{align*}
\]

66. Instantaneous cooling loads are NOT equal to instantaneous heat gains because
(a) Heat gains are offset by cooling provided by the AC system [IES-2003]
(b) Indoor temperatures are lower
(c) Comfort conditions are maintained in the space
(d) Of the storage effect in the construction material of walls and roof
66. Ans. (d)
Answers with Explanation (Objective)