S K Mondal's

Refrigeration and Air-Conditioning

GATE, IES & IAS 20 Years Question Answers

Contents

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Note

If you think there should be a change in option, don't change it by yourself send me a mail at swapan_mondal_01@yahoo.co.in I will send you complete explanation.

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Every effort has been made to see that there are no errors (typographical or otherwise) in the material presented. However, it is still possible that there are a few errors (serious or otherwise). I would be thankful to the readers if they are brought to my attention at the following e-mail address: swapan_mondal_01@yahoo.co.in

S K Mondal

1. Heat Pump and Refrigeration Cycles and Systems

OBJECTIVE QUESTIONS (GATE, IES, IAS)

Previous 20-Years GATE Questions

Heat Engine, Heat Pump

GATE-1. The coefficient of performance (COP) of a refrigerator working as a heat pump is given by: [GATE-1995; IES-1992, 1994, 2000]

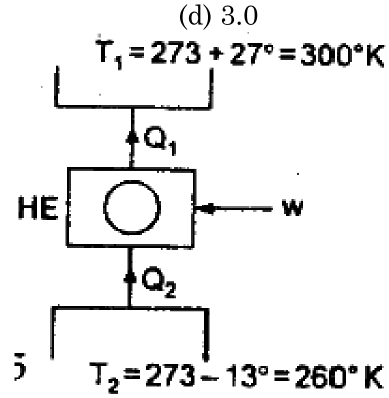
(a) $(COP)_{heat\ pump} = (COP)_{refrigerator} + 2$
(b) $(COP)_{heat\ pump} = (COP)_{refrigerator} + 1$
(c) $(COP)_{heat\ pump} = (COP)_{refrigerator} - 1$
(d) $(COP)_{heat\ pump} = (COP)_{refrigerator}$

GATE-1. Ans. (b) The COP of refrigerator is one less than COP of heat pump, if same refrigerator starts working as heat pump i.e. $(COP)_{heat\ pump} = (COP)_{refrigerator} + 1$

GATE-2. An industrial heat pump operates between the temperatures of 27°C and –13°C. The rates of heat addition and heat rejection are 750 Wand 1000 W, respectively. The COP for the heat pump is: [GATE-2003]

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

GATE-2. Ans. (c) $(COP)_{HP} = \frac{Q_1}{Q_1 - Q_2} = \frac{1000}{1000 - 750} = 4$



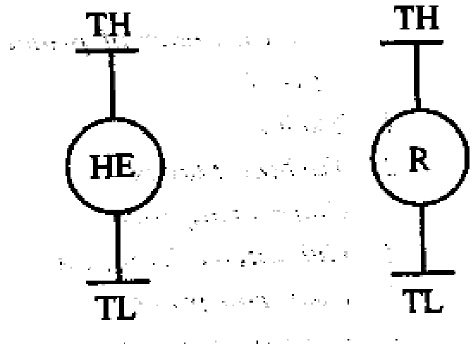
GATE-3. Any thermodynamic cycle operating between two temperature limits is reversible if the product of efficiency when operating as a heat engine and the coefficient of performance when operating as refrigeration is equal to 1.

GATE-3. Ans. False

Efficiency Heat engine, $\eta_{HE} = \left(\frac{T_H - T_L}{T_H}\right)$

COP of Refrigerator = $\frac{T_L}{T_H - T_L}$

Product of η_{HE} and $COP_R \neq 1$.



[GATE-1994]

GATE-4. An irreversible heat engine extracts heat from a high temperature source at a rate of 100 kW and rejects heat to a sink at a rate of 50 kW. The entire work output of the heat engine is used to drive a reversible heat pump operating between a set of independent isothermal heat reservoirs at 17^{0}C and 75^{0}C. The rate (in kW) at which the heat pump delivers heat to its high temperature sink is: [GATE -2009]

(a) 50 (b) 250 (c) 300 (d) 360

GATE-4. Ans. (c)

Reversed Carnot Cycle

GATE-5. A Carnot cycle refrigerator operates between 250K and 300 K. Its coefficient of performance is: [GATE-1999]

(a) 6.0 (b) 5.0 (c) 1.2 (d) 0.8

GATE-5. Ans. (b) $(COP)_R = \frac{T_2}{T_1 - T_2} = \frac{250}{300 - 250} = 5$

GATE-6. In the case of a refrigeration system undergoing an irreversible cycle, $\oint \frac{\delta Q}{T}$ is: [GATE-1995]

(a) < 0 (b) = 0 (c) > 0 (d) Not sure

GATE-6. Ans. (a)

Refrigeration capacity (Ton of refrigeration)

GATE-7. 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

GATE-7. Ans. (a) 211 kJ/min = 1 T refrigeration

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

Previous 20-Years IES Questions

Heat Engine, Heat Pump

IES-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? [IES-2007]

(a) 1 kW (b) 5 kW (c) 6 kW (d) None of the above

IES-1. Ans. (c) For heat pump $(COP)_{HP} = \frac{Q_1}{W} = \frac{T_1}{T_1 - T_2} = \frac{300}{300-250}$ or $Q_1 = 6 \times W = 6$ kW

IES-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? [IES-2006]

(a) 40·5 W (b) 405 W (c) 42·5 W (d) 425 W

IES-2. Ans. (b) $\left(COP\right)_{HP} = \frac{Q_1}{W} = \frac{T_1}{T_1 - T_2} = \frac{293}{15}$ or $W = \frac{7.9 \times 15}{293}\text{kW} = 405\,\text{W}$

IES-3. 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? [IES-2005]

(a) 2 (b) 3 (c) 4 (d) 5

IES-3. Ans. (d) $\frac{T_2}{T_1} = 0.8$ or $\left(COP\right)_{H.P} = \frac{T_1}{T_1 - T_2} = 5$

IES-4. 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? [IES-2003]

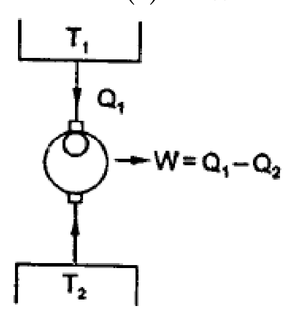
(a) 2 kW (b) 3 kW (c) 4 kW (d) 5 kW

IES-4. Ans. (c) For minimum power consumption,

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_1 - Q_2}{T_1 - T_2} = \frac{W}{T_1 - T_2}$$

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_1 - Q_2}{T_1 - T_2} = \frac{W}{T_1 - T_2}$$

$$W = Q_1 \times \frac{T_1 - T_2}{T_1} = \frac{80000}{3600} \times \frac{333-273}{333} = 4\text{ kW}$$



IES-5. Assertion (A): If a domestic refrigerator works inside an adiabatic room with its door open, the room temperature gradually decreases.
Reason (R): Vapour compression refrigeration cycles have high COP compared to air refrigeration cycles. [IES-2009]

(a)Both A and R are individually true and R is the correct explanation of A.
(b)Both A and R are individually true but R is not the correct explanation of A.
(c)A is true but R is false.
(d)A is false but R is true.

IES-5. Ans. (d)

IES-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:

(a) 1 KW (b) 4 KW (c) 5 KW (d) 6 KW **[IES-2003]**

IES-6. Ans. (c) $(COP)_{\text{Heat pump}} = (COP)_{\text{refrigerator}} + 1 = 4 + 1 = 5$

or $(COP)_{\text{Heat pump}} = \dfrac{Q_1}{W} = \dfrac{\text{Heating effect}}{\text{work input}}$

or Heating effect, $Q_1 = W \times (COP)_{\text{Heat pump}} = 5 \text{ kW}$

IES-7. Assertion (A): An air-conditioner operating as a heat pump is superior to an electric resistance heater for winter heating. [IES-2009]
Reason (R): A heat pump rejects more heat than the heat equivalent of the heat absorbed.
(a)Both A and R are individually true and R is the correct explanation of A.
(b)Both A and R are individually true but R is not the correct explanation of A.
(c)A is true but R is false.
(d)A is false but R is true.

IES-7. Ans. (a)

IES-8. The coefficient of performance (COP) of a refrigerator working as a heat pump is given by: [IES-1992, 1994, 2000; GATE-1995]
(a) $(COP)_{\text{heat pump}} = (COP)_{\text{refrigerator}} + 2$
(b) $(COP)_{\text{heat pump}} = (COP)_{\text{refrigerator}} + 1$
(c) $(COP)_{\text{heat pump}} = (COP)_{\text{refrigerator}} - 1$
(d) $(COP)_{\text{heat pump}} = (COP)_{\text{refrigerator}}$

IES-8. Ans. (b) The COP of refrigerator is one less than COP of heat pump, if same refrigerator starts working as heat pump i.e. $(COP)_{\text{heat pump}} = (COP)_{\text{refrigerator}} + 1$

IES-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

IES-9. Ans. (c) COP of heat pump $= \dfrac{T_1}{T_1 - T_2} = \dfrac{600}{600 - 300} = 2$

IES-10. The thermal efficiency of a Carnot heat engine is 30%. If the engine is reversed in operation to work as a heat pump with operating conditions unchanged, then what will be the COP for heat pump? [IES-2009]
(a) 0.30 (b) 2.33 (c) 3.33 (d) Cannot be calculated

IES-10. Ans. (c) Thermal Efficiency = 0.3

$$\Rightarrow \; 1 - \frac{T_2}{T_1} = 0.3 \qquad \Rightarrow \; \frac{T_2}{T_1} = 0.7$$

$$\text{COP of heat pump} = \frac{T_1}{T_1 - T_2} = \frac{1}{1 - 0.7} = \frac{1}{0.3} = 3.33$$

IES-11. Operating temperature of a cold storage is –2°C From the surrounding at ambient temperature of 40 heat leaked into the cold storage is 30 kW. If the actual COP of the plant is 1/10th of the maximum possible COP, then what will be the power required to pump out the heat to maintain the cold storage temperature at –2°C? [IES-2009]
(a) 1.90 kW (b) 3.70 kW (c) 20.28 kW (d) 46.50 kW

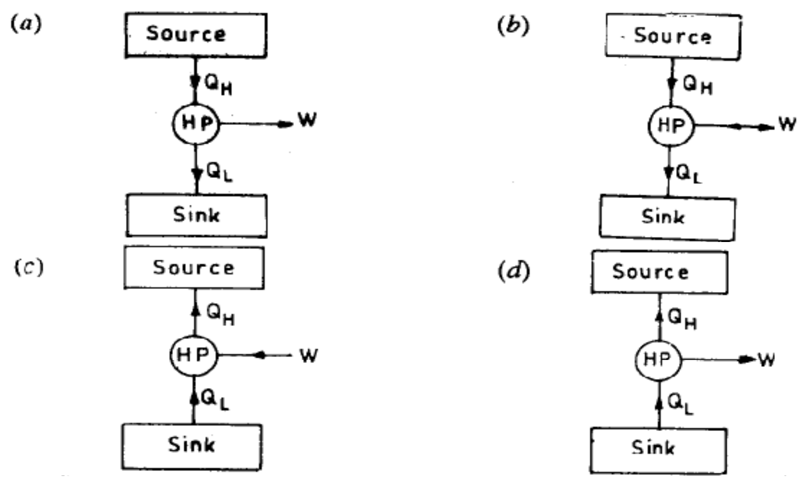
IES-11. Ans. (d) Actual COP $= \dfrac{RE}{W} \quad \Rightarrow \; \dfrac{1}{10}\left(\dfrac{271}{313 - 271}\right) = \dfrac{30}{W} \quad \Rightarrow \; W = 46.50 \text{ KW}$

IES-12. 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.
(a)Both A and R are individually true and R is the correct explanation of A
(b)Both A and R are individually true but R is **not** the correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

IES-12. Ans. (a)

IES-13. A heat pump is shown schematically as [IES-1994]



IES-13. Ans. (c) In heat pump, heat is rejected to source, work done on compressor, and heat absorbed from sink.

IES-14. A heat pump working on a reversed Carnot cycle has a C.O.P. of 5. lf 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

IES-14. Ans. (d) COP heat pump $= \dfrac{\text{Work done}}{\text{Heat rejected}}$ or heat rejected = 5 × work done

And heat rejected = refrigeration effect + work input
or, 5 × work input – work input = refrigeration effect
or, 4 × work input = refrigeration effect
or refrigeration effect = 4 × 1 kW = 4 kW

IES-15. Assertion (A): The coefficient of performance of a heat pump is greater than that for the refrigerating machine operating between the same temperature limits.[IES-2002; IAS-2002]
Reason (R): The refrigerating machine requires more energy for working where as a heat pump requires less.
(a)Both A and R are individually true and R is the correct explanation of A
(b)Both A and R are individually true but R is **not** the correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

IES-15. Ans. (c) R is false. For refrigerating machine our aim is to extract heat from lower temperature source. In heat pump we are interested on heat addition to higher temperature side so it is heat extracted + work added. That so why it's COP is higher but work requirement is same for both the machine.

IES-16. The refrigerating efficiency that is the ratio of actual COP to reversible COP of a refrigeration cycle is 0.8, the condenser and evaporator temperatures are 50°C and –30°C respectively. If cooling capacity of the plant is 2.4 kW then what is the work requirement? [IES-2009]

(a) 1.00 kW (b) 1.33 kW (c) 1.25 kW (d) 2.08 kW

IES-16. Ans. (a) Condenser Temperature = 273 + 51 = 324 K

Evaporator Temperature = 273 – 30 = 243 K

$$\text{Actual COP} = 0.8\times\frac{243}{324-243}$$

∵ We know that

$$\text{Actual COP} = \frac{R.E}{W} \quad\Rightarrow\quad 0.8\times\frac{243}{324-243}=\frac{2.4}{W} \quad\Rightarrow\quad W = 1.00\text{ kW}$$

Reversed Carnot Cycle

IES-17. 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? [IES-2005]

(a) 3 (b) 4.5 (c) 5.8 (d) 7.0

IES-17. Ans. (a) $W=\dfrac{700}{10}$ kJ/min, $Q = 210$ kJ/min, $COP=\dfrac{210}{70}=3$

IES-18. 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: [IES-1999; IAS-2003]

(a) 1.2 (b) 1.25 (c) 3.33 (d) 4

IES-18. Ans. (b) $(\text{COP})_{\text{Refrigerator}}$ of reversed Carnot cycle $=\dfrac{T_2}{T_1-T_2}=\dfrac{1}{\dfrac{T_1}{T_2}-1}=4$

or $\dfrac{T_1}{T_2}-1=0.25$ or $\dfrac{T_1}{T_2}=1.25$

IES-19. 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: [IES-1997]

(a) 6.5 (b) 7.5 (c) 10.5 (d) 15.0

IES-19. Ans. (a) $COP=\dfrac{T_1}{T_2-T_1}=\dfrac{(273-13)}{(273+27)-(273-13)}=6.5$

IES-20. 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

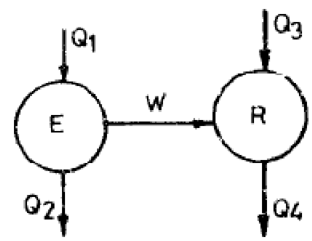
IES-20. Ans. (c) $COP=\dfrac{T_2}{T_1-T_2}=\dfrac{200}{300-200}=2=\dfrac{Q}{W}$

Given, $Q = 2$ kW; $\therefore W = \frac{Q}{2} = 1$ kW

IES-21. A Carnot refrigerator requires 1.5 kW/ton of refrigeration to maintain a region at a temperature of – 30°C. The COP of the Carnot refrigerator is:
(a) 1.42 (b) 2.33 (c) 2.87 (d) 3.26 **[IES-2003]**

IES-21. Ans. (b) COP of carnot refrigerator $= \frac{Q_2}{W} = \frac{3.5}{1.5} = 2.33$ $\left[\text{As } 1\text{ TR} \approx 3.5 \text{ kW}\right]$

IES-22. 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

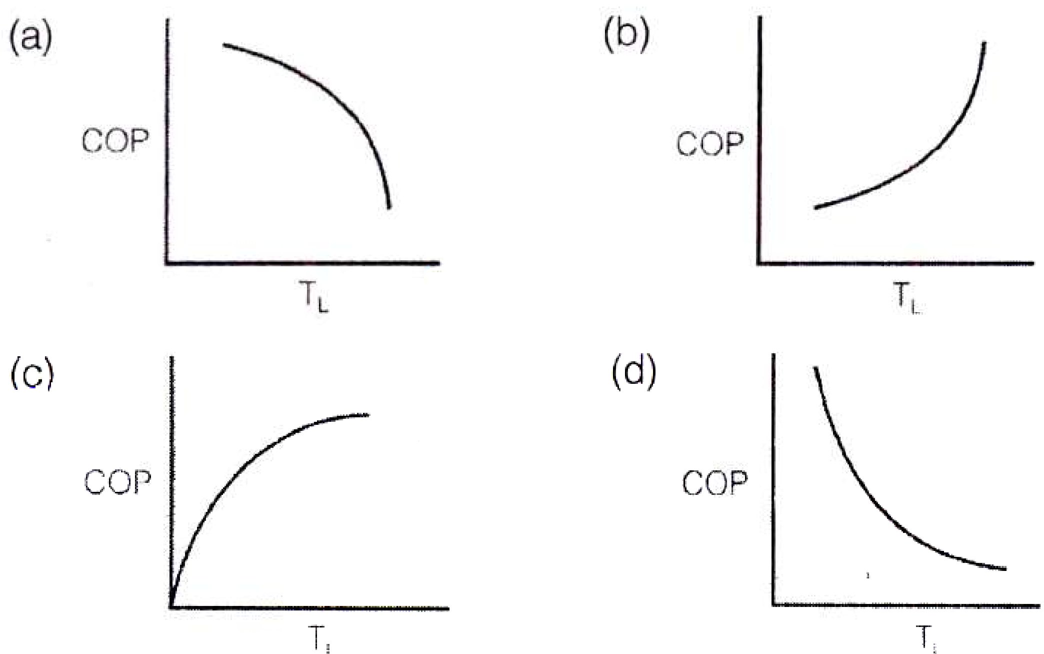


[IES-1992]

IES-22. 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 = $\frac{Q_3}{W} = \frac{Q_3}{Q_1 - Q_2} = \frac{2Q_1}{Q_1 - 0.6Q_1} = 5$

IES-23. For a given value of T_H (Source temperature) for a reversed Carnot cycle, the variation of T_L (Sink temperature) for different values of COP is represented by which one of the following graphs? **[IES-2009]**



IES-23. Ans. (c) $COP = \dfrac{T_L}{T_H - T_L}$

COP is on y-axis and T_L on x-axis

$\therefore \quad y = \dfrac{x}{K - x}$

$\Rightarrow$ Curve (C) is the correct representation of above equation since it passes through the origin.

Production of Solid Ice

IES-24. In a vapour compression refrigeration cycle for making ice, the condensing temperature for higher COP [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

IES-24. Ans. (c)

IES-25. 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.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-25. Ans. (c) A is true but R is false.

Refrigeration capacity (Ton of refrigeration)

IES-26. One ton refrigeration is equivalent to: [IES-1999]

(a) 3.5 kW (b) 50 kJ/s (c) l000 J/min (d) 1000 kJ/min

IES-26. Ans. (a)

IES-27. 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) [IES-2001; 2003]

(a) 3.5°C (b) 6.3°C (c) 23.7 °C (d) 15°C

IES-27. Ans. (d) $3.516 \times 3600 = 4.18 \times 200 \times (300 - x)$

or $x = 14.98°C \approx 15°C$

IES-28. 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? [IES-2007]

(a) 80 kW (b) 60 kW (c) 20 kW (d) 10 kW

IES-28. Ans. (d) COP = $\dfrac{Q}{W}$ or $W = \dfrac{Q}{COP} = \dfrac{1200}{60 \times 2}$ = 10 kW

IES-29. A Carnot refrigerator has a COP of 6. What is the ratio of the lower to the higher absolute temperatures? [IES-2006]

(a) 1/6 (b) 7/8 (c) 6/7 (d) 1/7

IES-29. Ans. (c) $(COP)_R = \frac{T_2}{T_1 - T_2} = 6$ or $\frac{T_1}{T_2} = 1 + \frac{1}{6} = \frac{7}{6}$; $\therefore \frac{T_2}{T_1} = \frac{6}{7}$

IES-30. A reversed Carnot cycle working as a heat pump has a COP of 7. What is the ratio of minimum to maximum absolute temperatures? [IES-2005]

(a) 7/8 (b) 1/6 (c) 6/7 (d) 1/7

IES-30. Ans. (c) $(COP)_{H.P} = \frac{T_1}{T_1 - T_2} = 7$ or $\frac{T_1 - T_2}{T_1} = \frac{1}{7}$ or $\frac{T_2}{T_1} = \frac{6}{7}$

IES-31. Which one of the following statements is correct? [IES-2004]
In a domestic refrigerator periodic defrosting is required because frosting

(a) Causes corrosion of materials (b)Reduces heat extraction
(c) Overcools food stuff (d)Partially blocks refrigerant flow

IES-31. Ans. (b)

IES-32. Consider the following statements: [IES-1997]
In the thermoelectric refrigeration, the coefficient of performance is a function of:

1. Electrical conductivity of materials
2. Peltier coefficient
3. Seebeck coefficient
4. Temperature at cold and hot junctions
5. Thermal conductivity of materials.

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

IES-32. Ans. (c)

IES-33. When the lower temperature is fixed, COP of a refrigerating machine can be improved by: [IES-1992]

(a) Operating the machine at higher speeds
(b) Operating the machine at lower speeds
(c) Raising the higher temperature
(d) Lowering the higher temperature

IES-33. 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.

IES-34. 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? [IES-2005]

(a) 50 litres/hour (b) 75 litres/hour (c) 100 litres/hour (d) 125 litres/hour

IES-34. Ans. (c) $Q = \dot{m} C_P \Delta t$ or $0.5 \times 12660 = \dot{m} \times 4.2 \times (30 - 15)$ or $\dot{m} = 100$ kg/hr

Previous 20-Years IAS Questions

Heat Engine, Heat Pump

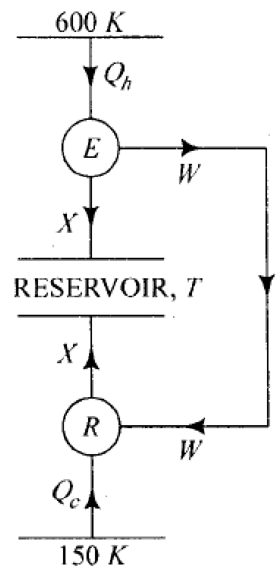
IAS-1. A building in a cold climate is to be heated by a Carnot heat pump. The minimum outside temperature is –23°C. If the building is to be kept at 27°C and heat requirement is at the rate of 30 kW, what is the minimum power required for heat pump? [IAS-2007]

(a) 180 kW (b) 30 kW (c) 6 kW (d) 5 kW

IAS-1. Ans. (d) $(\text{COP})_{\text{H.P}} = \dfrac{Q_1}{W} = \dfrac{T_1}{T_1 - T_2}$ or $W = Q_1\left(1 - \dfrac{T_2}{T_1}\right) = 30 \times \left(1 - \dfrac{250}{300}\right) = 5$ KW

IAS-2. In the system given above, the temperature T = 300 K. When is the thermodynamic efficiency σE 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



[IAS-2007]

IAS-2. Ans. (a) $\eta_E = 1 - \dfrac{300}{600} = \dfrac{1}{2} = \dfrac{1}{COP}$ or $COP = 2$

$$(COP)_{H.P} = \frac{300}{300-150} = 2 \text{ and } (COP)_R = \frac{150}{300-150} = 1$$

$\therefore$ R must act as a Heat pump

IAS-3. Assertion (A): The coefficient of performance of a heat pump is greater than that for the refrigerating machine operating between the same temperature limits.[IAS-2002; IES-2002]
Reason (R): The refrigerating machine requires more energy for working where as a heat pump requires less.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-3. Ans. (c) R is false. For refrigerating machine our aim is to extract heat from lower temperature source. In heat pump we are interested on heat addition to higher temperature side so it is heat extracted + work added. That so why it's COP is higher but work requirement is same for both the machine.

IAS-4. 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 **[IAS-2001]**

IAS-4. Ans. (b) $(COP)_{HP} = \dfrac{T_1}{T_1 - T_2}$ and $\eta = \dfrac{T_1 - T_2}{T_1} = \dfrac{1}{(COP)_{HP}} = \dfrac{1}{5} = 0.2$

IAS-5. 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: [IAS-1996]

(a) 0.5 (b) 2.0 (c) 28.3 (d) 29.3

IAS-5. Ans. (d) $COP = \dfrac{T_1}{T_1 - T_2} = \dfrac{293}{293-283} = 29.3$

IAS-6. **Assertion (A):** Although a heat pump is a refrigerating system, the coefficient of performance differs when it is operating on the heating cycle. **[IAS-1994]**
Reason(R): It is condenser heat that is useful (the desired effect) instead of the refrigerating effect.
(a)Both A and R are individually true and R is the correct explanation of A
(b)Both A and R are individually true but R is **not** the correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

IAS-6. Ans. (a)

IAS-7. **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:** **[IAS-1995]**
(a) 100 kJ (b) 60 kJ (c) 40 kJ (d) 88 kJ

IAS-7. Ans. (c) Maximum efficiency for 227° and 27°C sources = $\dfrac{500-300}{500} = 0.4$

∴ Maximum work available for a heat input of 100 kJ = 0.4 × 100 = 40 kJ.

Reversed Carnot Cycle

IAS-8. **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:** **[IAS-2003; IES-1999]**
(a) 1.2 (b) 1.25 (c) 3.33 (d) 4

IAS-8. Ans. (b) $(\text{COP})_{Refrigerator}$ of reversed Carnot cycle $= \dfrac{T_2}{T_1 - T_2} = \dfrac{1}{\dfrac{T_1}{T_2} - 1} = 4$

or $\dfrac{T_1}{T_2} - 1 = 0.25$ or $\dfrac{T_1}{T_2} = 1.25$

IAS-9. **A refrigeration system operates on the reversed Carnot cycle. The temperature for the system is: Higher temperature = 40°C and Lower temperature = 20°C.** **[IAS-2007]**
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?
(a) 1·25 kJ/hr (b) 1·55 kJ/hr (c) 2·3 kJ/hr (d) None of the above

IAS-9. Ans. (d) $COP = \dfrac{T_2}{T_1 - T_2} = \dfrac{293}{213-293} = \dfrac{293}{20} = \dfrac{Q_2}{W}$

$Q_2 = 10 \times 14000 \text{ KJ/hr}$ or $W = 14 \times 10^4 \times \dfrac{20}{293}$ KJ/hr

$$Q_1 = Q_2 + W = 14\times10^4 + 14\times10^4 \times \frac{20}{293} = 14\times10^4\left(1+\frac{20}{293}\right) \text{KJ/hr} = 150 \text{ MJ/hr}$$

IAS-10. **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. COP and power consumed by the cycle will, respectively, be:** **[IAS-2004; IES-1997]**

(a) 1 and 1 kW (b) 1 and 2 kW (c) 2 and 1 kW (d) 2 and 2 kW

IAS-10. Ans. (c) $COP = \dfrac{T_2}{T_1 - T_2} = \dfrac{200}{300-200} = 2 = \dfrac{Q}{W}$

Given, $Q = 2$ kW; $\therefore\ W = \dfrac{Q}{2} = 1$ kW

IAS-11. 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:
(a) 317.88 (b) 43.88 (c) 23 (d) Zero **[IAS-1997]**

IAS-11. Ans. (b) $COP = \dfrac{Q}{W} = \dfrac{T_2}{T_1 - T_2}$ or, $\dfrac{(1000/60)}{6} = \dfrac{233}{T_1 - 233}$

or, $T_1 - 233 = 83.88$ or, $T_1 = 316.88\,K = 43.88°\text{C}$

IAS-12. The COP 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

IAS-12. Ans. (c) COP of Carnot refrigerator $\dfrac{T_2}{T_1 - T_2}$ will decrease if upper temperature T_1 is increased and T_2 keeping const.

IAS-13. The efficiency of a Carnot engine is given as 0·75. If the cycle direction is reversed, what will be the value of COP for the Carnot refrigerator? **[IAS-2002]**
(a) 0·27 (b) 0·33 (c) 1·27 (d) 2·33

IAS-13. Ans. (b) 1st method: $(COP)_R = (COP)_{H.P} - 1 = \dfrac{1}{\eta_{\text{Carnot}}} - 1 = \dfrac{1}{0.75} - 1 = 0.33$

2nd method: $\eta_{\text{Carnot}} = 1 - \dfrac{T_2}{T_1} = 0.75$ or $\dfrac{T_2}{T_1} = \dfrac{1}{4}$ $or\ \dfrac{T_2}{T_1 - T_2} = \dfrac{1}{4-1} = 0.33 = (COP)_R$

IAS-14. 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: **[IAS-2000]**
(a) 0.5 kW (b) 0.67 kW (c) 1.5 kW (d) 3 kW

IAS-14. Ans. (a) $COP = \dfrac{Q}{W} = \dfrac{T_2}{T_1 - T_2}$ or, $W = \dfrac{1\times(300-200)}{200}$ KW =0.5 KW

IAS-15. 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 × 10⁶ kJ/h of energy is to be continuously removed from the cold storage, the MINIMUM power required to run the refrigerator will be: **[IAS-1997]**
(a) 14.3 kW (b) 75.3 kW (c) 154.3 kW (d) 245.3 kW

IAS-15. Ans. (c) Maximum COP$= \dfrac{T_2}{T_1 - T_2} = \dfrac{270}{300-270} = 9 = \dfrac{Q}{W_{\min}}$

or $W_{\min} = \dfrac{Q}{9} = \dfrac{5\times10^6}{9\times3600}$ kW $= 154.3$ kW

IAS-16. 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: **[IAS-1996]**

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

IAS-16. Ans. (a) $0.4 = \dfrac{W}{Q_1}$..............(i) and $5 = \dfrac{Q_2}{W}$.................(ii)

$\therefore\ 0.4Q_1 = \dfrac{Q_2}{5}$ or $Q_1 = 0.5Q_2$

IAS-17. 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: **[IAS-1994, 1995]**

(a) 3.33 (b) 3.00 (c) 2.33 (d) 1.33

IAS-17. Ans. (c) η Carnot engine $= \dfrac{T_1 - T_2}{T_1} = 0.3 \quad \Rightarrow 1 - \dfrac{T_2}{T_1} = 0.3$

$$\text{COP Carnot refrigerator} = \frac{T_2}{T_1 - T_2} = \frac{T_2}{0.3\,T_1} = \frac{1}{0.3} = \frac{T_2}{T_1} = \frac{1}{0.3}\times 0.7 = \frac{7}{3} = 2.33$$

Production of Solid Ice

IAS-18. **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. **[IAS-1997]**

Reason (R): The triple point of CO_2 is at about 5 atmospheric pressure and at 216 K.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-18. Ans. (a)

Refrigeration capacity (Ton of refrigeration)

IAS-19. **Assertion (A):** The COP of an air-conditioning plant is lower than that of an ice plant. **[IAS-1997]**

Reason (R): The temperatures required in the ice plant are lower than those required for an air-conditioning plant.

(a)Both A and R are individually true and R is the correct explanation of A
(b)Both A and R are individually true but R is **not** the correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

IAS-19. Ans. (d) The COP of an air-conditioning plant is higher than that of an ice plant.

IAS-20. The power (kW) required per ton of refrigeration is $\dfrac{N}{COP}$, 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

IAS-20. Ans. (b) $COP = \dfrac{\dot{Q}}{W}$ or $W = \dfrac{\dot{Q}}{COP}$; if W is in KW, $\dot{Q} = \dfrac{12660}{3600}$ kW $= 3.52$ kW

IAS-21. **Assertion (A):** Power input per TR of a refrigeration system increases with decrease in evaporator temperature. **[IAS-2004]**

Reason (R): COP of refrigeration system decreases with decrease in evaporator temperature.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-21. Ans. (a)

2. Vapour Compression System

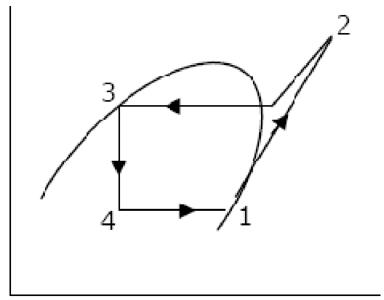
OBJECTIVE QUESTIONS (GATE, IES, IAS)

Previous 20-Years GATE Questions

Vapour Compression Cycle

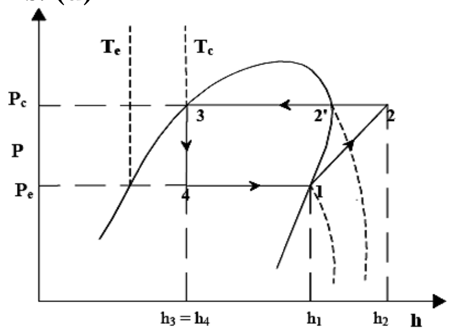
GATE-1. The vapour compression refrigeration cycle is represented as shown in the figure below, with state 1 being the exit of the evaporator. The coordinate system used in this figure is:

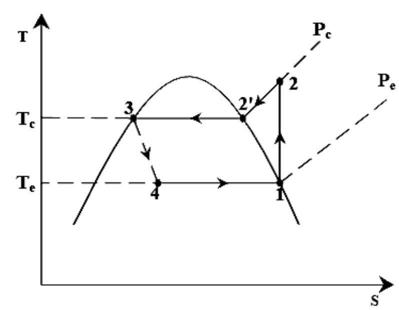
(a) *p-h* (b) *T-s*
(c) *p-s* (d) *T-h*



[GATE-2005]

GATE-1. Ans. (d)





GATE-2. In a vapour compression refrigeration system, liquid to suction heat exchanger is used to: [GATE-2000]

(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-2. Ans. (c)

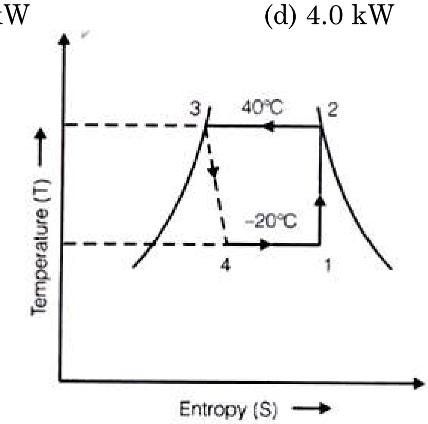
Data for Q3–Q4 are given below. Solve the problems and choose correct answers.

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:

$T(^0C)$	H_f(kJ/kg)	Hg(kJ/kg)	s_f(kJ/kg K)	s_g(kJ/kg K)
-20	20	180	0.07	0.7366
40	80	200	0.3	0.67

GATE-3. 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

GATE-3. Ans. (a) $h_2 = 200$ kJ/kg
$S_2 = 0.67$ kJ/kg-K
$h_4 = h_3 = 80$ kJ/kg



First calculating quality (x) of vapour

$$S_2 = S_1$$
$$\Rightarrow S_2 = 0.07 + x(0.7366 - 0.07)$$
$$\Rightarrow 0.67 = 0.07 + 0.6666x$$

Enthalpy at point 1, we get
$h_1 = 20 + 0.90\ (180 - 20)$
$= 20 + 0.90 \times 160$
$h_1 = 164$ kJ/kg

Refrigerant effect = $m(h_1 - h_2) = 0.025(164 - 80) = 2.1$ KW

GATE-4. The COP of the refrigerator is: [GATE-2003]
(a) 2.0 (b) 2.33 (c) 5.0 (d) 6.0

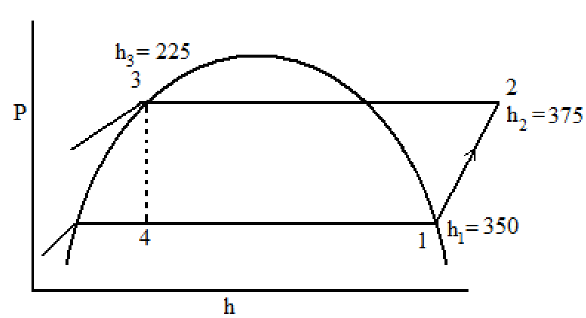
GATE-4. Ans. (b) $COP = \dfrac{h_1 - h_4}{h_2 - h_1} = \dfrac{164 - 80}{200 - 164} = 2.33$

Previous 20-Years IES Questions

Vapour Compression Cycle

IES-1. In a vapour compression refrigeration plant, the enthalpy values at different points are: [IES-2006]
(i)Enthalpy at exit of the evaporator = 350 kJ/kg
(ii)Enthalpy at exit of the compressor 375 kJ/kg
(iii)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

IES-1. Ans. (a) $h_3 = h_4$



Refrigerating effect (Q_o)
$= (h_1 - h_4) \times \eta_r$
$= (350 - 225) \times 0.8$
$= 100$ 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

IES-2. 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

IES-2. Ans. (c) $COP=\frac{(h_1-h_4)}{(h_2-h_1)}=\frac{(185-85)}{(210-185)}=\frac{100}{25}=4$

IES-3. For simple vapour compression cycle, enthalpy at suction = 1600 kJ/kg, enthalpy at discharge from the compressor = 1800 kJ/kg, enthalpy at exit from condenser = 600 kJ/kg. [IES-2008]
What is the COP for this refrigeration cycle?

(a) 3·3 (b) 5·0 (c) 4 (d) 4·5

IES-3. Ans. (b) COP of refrigeration cycle = $\frac{RE}{W}=\frac{1600-600}{1800-1600}=\frac{1000}{200}=5$

IES-4. 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.

IES-4. Ans. (a)

IES-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

IES-5. Ans. (c) $Q=\dot{m}(h_1-h_4)=1\times(195-65)=130\,\text{kW}$

IES-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

IES-6. Ans. (a)

IES-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

IES-7. Ans. (b)

IES-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 [IES-2001]

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

IES-8. Ans. (d)

IES-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:[IES-2000]

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

IES-9. Ans. (c)

IES-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: [IES-1999]

(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

IES-10. Ans. (c)

IES-11. The correct sequence of the given components of a vapour compression refrigerator is: [IES-1999]

(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

IES-11. Ans. (c)

IES-12. Consider the following statements: [IES-1998]
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

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

IES-13. Consider the following statements: [IES-1997]
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

IES-13. Ans. (a)

IES-14. A single-stage vapour compression refrigeration system cannot be used to produce ultralow temperatures because [IES-1997]
(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

IES-14. Ans. (c)

IES-15. In a vapour compression refrigeration system, a throttle valve is used in place of an expander because [IES-1996]
(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.

IES-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.

IES-16. 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.
(a)Both A and R are individually true and R is the correct explanation of A
(b)Both A and R are individually true but R is **not** the correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

IES-16. Ans. (b) A and R are true. But R is not right reasoning for A.
In vapour compression refrigeration system throttle valve is used and not expansion cylinder because the power produced by expansion cylinder is very low.

IES-17. Consider the following statements: [IES-1995]
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.

IES-17. Ans. (c)

IES-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: [IES-1993]
(a) 70 kW (b) 100 kW (c) 130 kW (d) 160 kW

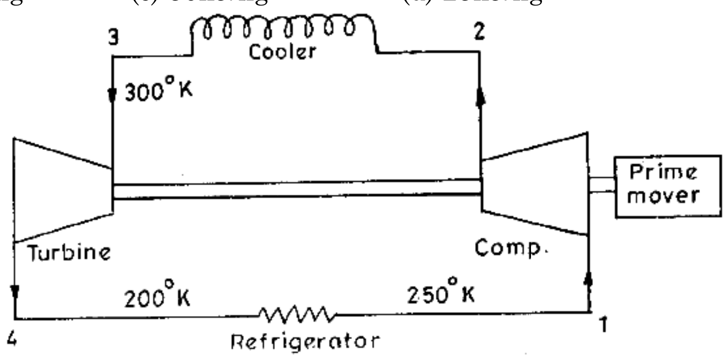
IES-18. Ans. (c) h_1 = 195 kJ/kg and h_3 = 65 kJ/kg.
Since there is no heat transfer in throttling, $h_3 = h_4$
Refrigeration effect = $h_1 - h_4$ = 195 – 65 = 130 kJ/kg

IES-19. Which one of the following expansion processes takes place in a vapour compression cycle? [IES-2009]
(a)Polytropic process with change in temperature
(b)Adiabatic process with work transfer
(c)Lsentropic process with change in enthalpy
(d)Adiabatic process with constant enthalpy

IES-19. Ans. (d)

IES-20. A refrigerating system operating on 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 = kJ per kg per °C) [IES-1993]
(a) 250 kJ/kg (b) 200 kJ/kg (c) 50kJ/kg (d) 25kJ/kg

IES-20. 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 × C_p = 25 kJ/kg

Actual Vapour Compression Cycle

IES-21. 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.
(a)Both A and R are individually true and R is the correct explanation of A
(b)Both A and R are individually true but R is **not** the correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

IES-21. Ans. (c) Sub cooling↑ Refrigerating effect thus↑ COP but has no effect on compressor work (W_c).

IES-22. Sub-cooling with regenerative 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

IES-22. Ans. (c)

IES-23. Match items in List-I with those in List-II and List-III and select the correct answer. [IES-1996]

	List-I		List-II		List-III
A.	Reversed Carnot engine	**1.**	Condenser	**6.**	Generator
B.	Subcooling	**2.**	Evaporator	**7.**	Increase in refrigerating effect
C.	Superheating	**3.**	Vortex refrigerator	**8.**	Highest COP
D.	Constant enthalpy	**4.**	Throttling	**9.**	Adiabatic
		5.	Heat pump	**10.**	Dry compression

Codes:

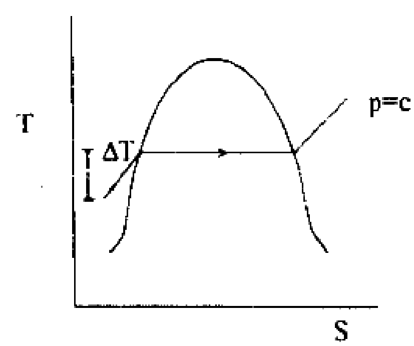
	A	B	C	D
(a)	3, 10	1, 7	2, 9	4, 6
(b)	5, 8	1, 7	2, 10	4, 9
(c)	4, 10	3, 8	3, 10	1, 6
(d)	2, 7	5, 8	4, 6	1, 9

IES-23. 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. Sub cooling occurs in condenser and it increases refrigeration effect. Therefore for B, the correct choice from List-II and List-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 List-III is 2, 10. Constant enthalpy process takes place during throttling and is basically adiabatic process. This D is matched with 4, 9.

IES-24. The figure given above depicts saturation dome for water on the temperature-entropy plane. What is the temperature difference ΔT 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



[IES-2006]

IES-24. Ans. (c)

IES-25. 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:

(a) 1.86 kW (b) 3.72 kW (c) 7.44 kW (d) 18.60 kW **[IES-1994]**

IES-25. 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

$$COP = \frac{\text{Heat abstracted}}{\text{Work required}} \quad \text{or} \quad \text{Work required} = \frac{30}{1.61} = 18.6 \text{ KW}$$

IES-26. Consider the following steps: **[IES-1994]**

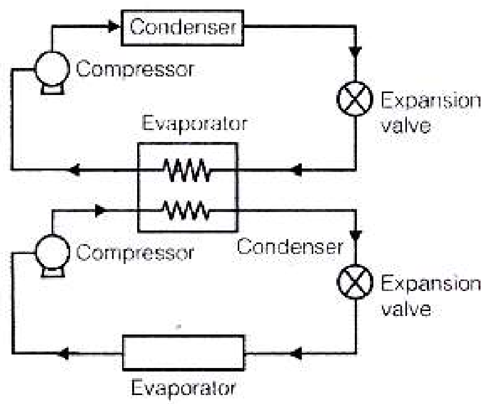
1. **Starting of compressor**
2. **Starting of cooling tower pump**
3. **Starting of chiller water pump**
4. **Starting of blower motor of cooling coil**

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

IES-26. 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.

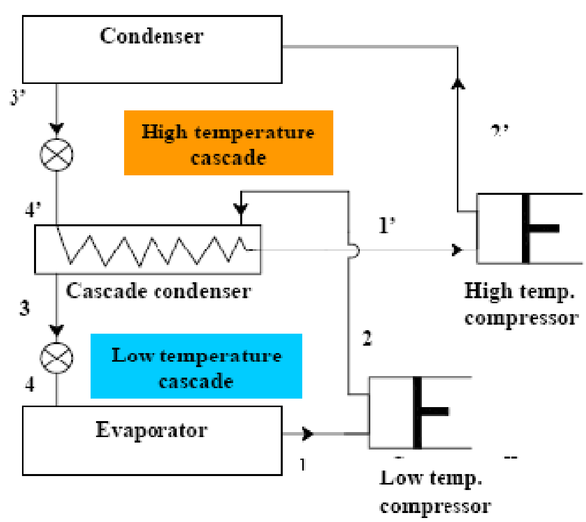
IES-27. Which one of the following statements is correct with respect to the schematic diagram as shown above?



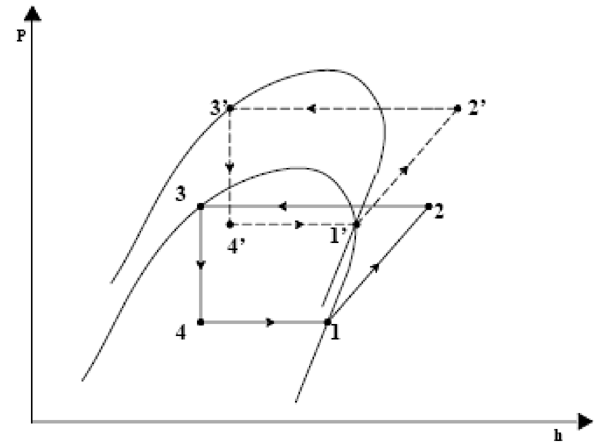
(a) Multi-evaporator vapour compression system of refrigeration
(b) Two stage compression vapour compression refrigeration system
(c) Cascade system of vapour compression refrigeration system
(d) None of the above

[IES-2009]

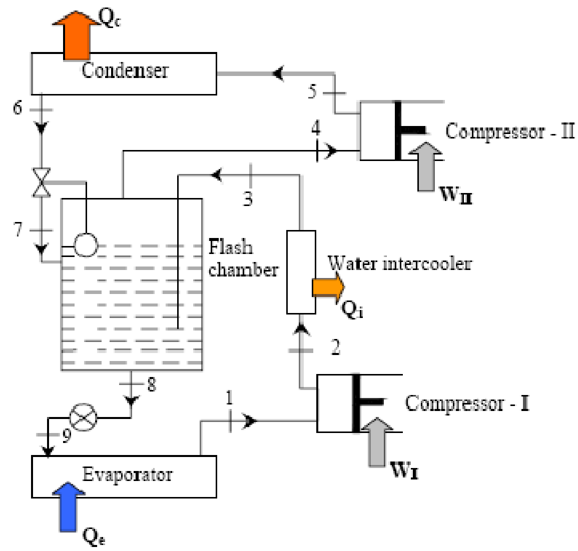
IES-27. Ans. (c)



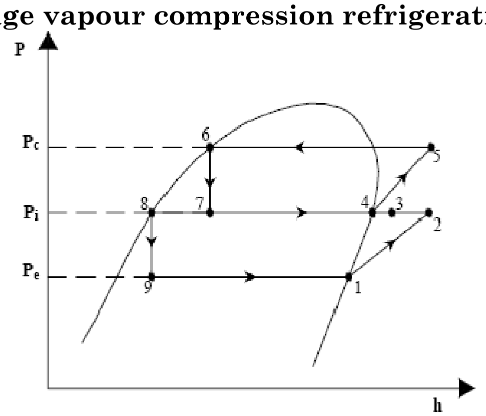
A two-stage cascade refrigeration system



A two-stage cascade refrigeration system



Two-stage vapour compression refrigeration system

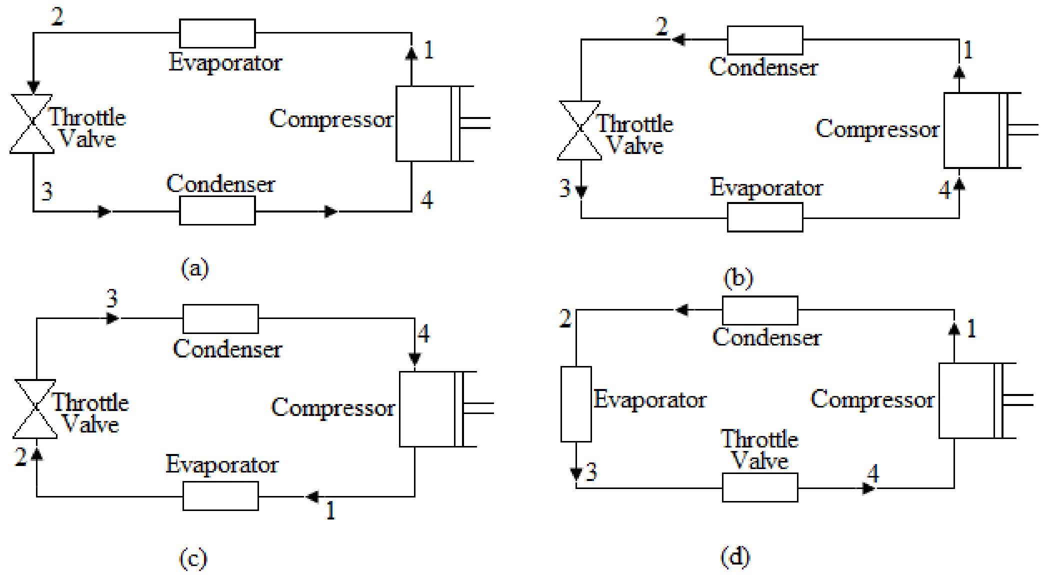


Two-stage vapour compression refrigeration system

Previous 20-Years IAS Questions

Modifications in Reversed Carnot Cycle with Vapour as a Refrigerant

IAS-1. The schematic diagram of a vapour compression refrigeration system can be represented as [IAS-1996]



IAS-1. Ans. (b)

Vapour Compression Cycle

IAS-2. 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

IAS-2. Ans. (d) Heat transfer co-efficient of gas very small compared to water $h_{water} >> h_{air}$. So for same heat transfer temperature difference will be high

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

IAS-3. Consider the following statements: [IAS-2007]
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

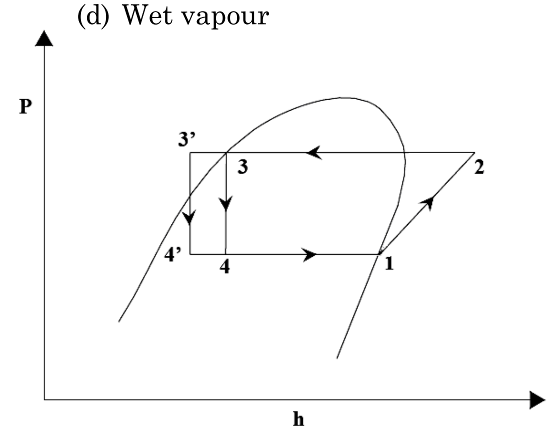
IAS-3. Ans. (a)

IAS-4. Consider the following statements pertaining to a vapour compression type refrigerator: [IAS-2002]
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

IAS-4. Ans. (b)

IAS-5. In a vapour compression cycle, the refrigerant, immediately after expansion value is: [IAS-2002]
(a) Saturated liquid (b) Subcooled liquid
(c) Dry vapour (d) Wet vapour

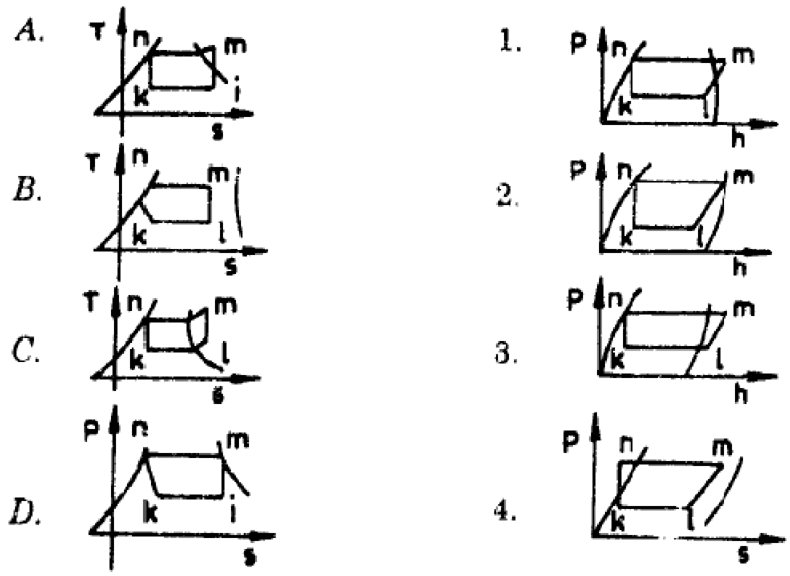
IAS-5. Ans. (d) In *P-h* diagram it is point 4' or 4 both are very wet vapour.



IAS-6. Assertion (A): In a vapour compression refrigeration system, the condenser pressure should be kept as low as possible. **[IAS-1999]**
Reason (R): Increase in condenser pressure reduces the refrigerating effect and increases the work of compression.
(a)Both A and R are individually true and R is the correct explanation of A
(b)Both A and R are individually true but R is **not** the correct explanation of A
(c)A is true but R is false
(d)A is false but R is true

IAS-6 Ans. (a)

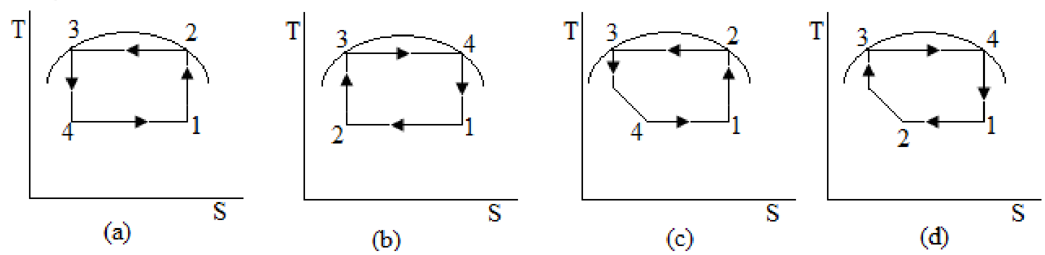
IAS-7. Match List-I (*T-s* diagram) with List-II (*P-h* diagrams) of vapour compression refrigeration cycles and select the correct answer using the codes given below the lists: [IAS-1999]
List-I List-II



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

IAS-7. Ans. (b)

IAS-8. **Theoretical vapour compression refrigeration cycle is represented on a *T-s* diagram as** **[IAS-1997]**



IAS-8. Ans. (c)

IAS-9. **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

IAS-9. Ans. (b) $Q = \dot{m}(h_1 - h_4) = \dot{m}(180 - 75) = 211$ or $\dot{m} = \dfrac{211}{105} = 2$ kg/min

IAS-10. **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:** **[IAS-1996]**
(a) 6 (b) 5 (c) 3.5 (d) 2.5

IAS-10. Ans. (b) $h_3 = h_4 = 80$ kJ/kg

$h_1 = 180$ kJ/kg and

$h_2 = 200$ kJ/kg

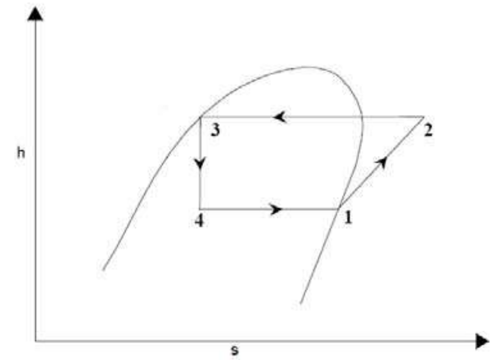
$W_C = h_2 - h_1$

$= 200 - 180 = 20$ KJ/kg

$Q = h_1 - h_4$

$= 180 - 80 = 100$ KJ/kg

$$\therefore\ COP = \frac{Q}{W_c} = \frac{100}{20} = 5$$



IAS-11. The correct sequence of vapour compression (VC), vapour absorption (VA) and steam ejector (SE) refrigeration cycles in increasing order of the COP is: [IAS-1995]

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

IAS-11. 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.

IAS-12. 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: [IAS-1997]

	List-I	List-II
A.	**Work input**	**1.Constant pressure at higher temperature**
B.	**Heat rejection**	**2.Isentropic compression**
C.	**Expansion**	**3.Constant temperature at lower pressure**
D.	**Heat absorption**	**4.Adiabatic**

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

IAS-12. Ans. (c)

Actual Vapour Compression Cycle

IAS-13. 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

IAS-13. Ans. (c) $(COP)_{actal} = \frac{1}{2}(COP)_{ideal} = \frac{1}{2} \times \frac{T_2}{T_1 - T_2} = \frac{1}{2} \times \frac{250}{300-250} = 2.5$

$$\text{Total Heat transfer}\,(Q) = m.c_{p_{bf}}\left(\Delta T\right)_{\text{before freeze}} + m.c_{p_{af}}\left(\Delta T\right)_{\text{after freeze}}$$

$$= 3600\,[2\times 30 + 230 + 0.5\times 20]\,\text{kJ} = 3600\times 300\,\text{kJ}$$

$$\text{Rate of heat transfer} = \frac{Q}{t} = \frac{3600\times 300}{10\times 3600} = 30\,\text{kW}$$

$$COP = \frac{\dot{Q}}{W} \text{ or } W = \frac{\dot{Q}}{COP} = \frac{30}{2.5} = 12\,\text{kW}$$

IAS-14. 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

IAS-14. Ans. (b)

IAS-15. Excessive pressure drop in liquid line in a refrigerating system causes [IAS-1998]
(a) High condenser pressure (b) Flashing of the liquid refrigerant
(c) Higher evaporator pressure (d) Under cooling of the liquid refrigerant

IAS-15. Ans. (b)

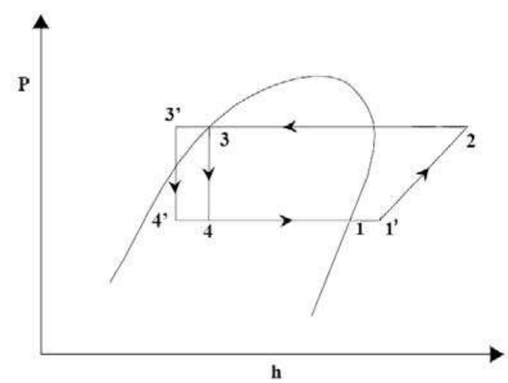
IAS-16. In system A vapour are superheated by 10°C in the evaporator while in system B vapour are superheated by 10°C in a liquid vapour regenerative heat exchanger, other conditions being the same. Then
(a) COP of A = COP of B **[IAS-2002]**
(b) COP of both A and B > COP of Reversed Carnot Cycle
(c) COP of A > COP of B
(d) COP of A < COP of B

IAS-16. Ans. (a) $h_{1'} - h_1 = h_3 - h_{3'}$

For regeneration as

$$h_{1'} - h_4 = h_1 - h_{4'}$$

$\therefore$ COP is same



3. Refrigerants

OBJECTIVE QUESTIONS (GATE, IES, IAS)

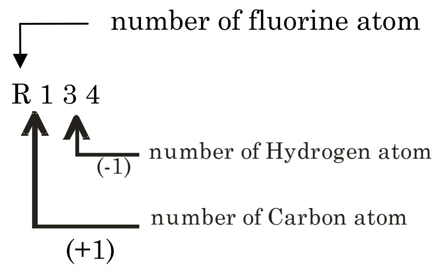
Previous 20-Years GATE Questions

Designation of Refrigerants

GATE-1. Environment friendly refrigerant R134$_a$ is used in the new generation domestic refrigerators. Its chemical formula is: [GATE-2004]

(a) CH ClF_2 (b) C_2 Cl_3 F_3 (c) C_2 Cl_2 F_4 (d) C_2 H_2 F_4

GATE-1. Ans. (d)



Hence answer is,$C_2H_2F_2$

Azeotropic Mixtures

GATE-2. 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

GATE-2. Ans. (d)

Previous 20-Years IES Questions

IES-1. A good refrigerant should have [IES-1992]

(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

IES-1. Ans. (a)

IES-2. The desirable combination of properties for a refrigerant include

(a)High specific heat and low specific volume **[IES-1998]**

(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

IES-2. Ans. (c) Required Properties of Ideal Refrigerant:

1. The refrigerant should have low boiling point and low freezing point.
2. It must have low specific heat and high latent heat. Because high specific heat decreases the refrigerating effect per kg of refrigerant and high latent heat at low temperature increases the refrigerating effect per kg of refrigerant.
3. The pressures required to be maintained in the evaporator and condenser should be low enough to reduce the material cost and must be positive to avoid leakage of air into the system.
4. It must have high critical pressure and temperature to avoid large power requirements.
5. It should have low specific volume to reduce the size of the compressor.
6. It must have high thermal conductivity to reduce the area of heat transfer in evaporator and condenser.
7. It should be non-flammable, non-explosive, non-toxic and non-corrosive.
8. It should not have any bad effects on the stored material or food, when any leak develops in the system.
9. It must have high miscibility with lubricating oil and it should not have reacting property with lubricating oil in the temperature range of the system.
10. It should give high COP in the working temperature range. This is necessary to reduce the running cost of the system.
11. It must be readily available and it must be cheap also.

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IES-3. Match List-I (Refrigerant) with List-II (Principal application) and select the correct answer using the codes given below the lists: [IES-1995]

List-I	List-II
A.Air	1.Direct contact freezing of food
B.Ammonia	2.Centrifugal compressor system

C.Carbon dioxide					**3.Large industrial temperature installation**				
D.Refrigerant-11					**4.Automotive air-conditioners**				
					5.Aircraft refrigeration				
Codes:	**A**	**B**	**C**	**D**		**A**	**B**	**C**	**D**
(a)	3	4	1	2	(b)	5	3	1	2
(c)	2	4	3	5	(d)	5	3	2	1

IES-3. Ans. (b)

IES-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: [IES-1993]
Codes: (a) 1 and 2 (b) 1, 2 and 3 (c) 1, 2 and 4 (d) 2, 3 and 4

IES-4. Ans. (c)

IES-5. In conventional refrigerants what is the element responsible for ozone depletion? [IES-2009]
(a) Chlorine (b) Fluorine (c) Carbon (d) Hydrogen

IES-5. Ans. (a) Ozone Depletion Potential (ODP): According to the Montreal protocol, the ODP of refrigerants should be zero, i.e., they should be non-ozone depleting substances. Refrigerants having non-zero ODP have either already been phased-out (e.g. R 11, R 12) or will be phased-out in near-future(e.g. R22). Since ODP depends mainly on the presence of chlorine or bromine in the molecules, refrigerants having either chlorine (i.e., CFCs and HCFCs) or bromine cannot be used under the new regulations.

IES-6. Which of the following refrigerant has the maximum ozone depletion in the stratosphere? [IES-1992]
(a) Ammonia (b) Carbon dioxide (c) Sulphur dioxide (d) Fluorine

IES-6. Ans. (d)

IES-7. Ozone depletion by CFCs occurs by breakdown of: [IES-2002]
(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

IES-7. Ans. (c)

IES-8. Which one of the following is correct? [IES-2008]
Environmental protection agencies advise against the use of chlorofluorocarbon refrigerants because these react with
(a)Water vapour and cause acid rain
(b)Plants and cause green house effect
(c)Oxygen and cause its depletion
(d)Ozone layer and cause its depletion

IES-8. Ans. (d)

Designation of Refrigerants

IES-9. Consider the following statements regarding refrigerants: [IES-2000]

1. Refrigerant NH_3 is used in reciprocating compressors.
2. Refrigerant CO_2 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

IES-9. Ans. (a)

IES-10. Match List-I (Refrigerant) with List-II (Chemical constituent) and select the correct answer using the codes given below the lists: [IES-2001]

List-I	List-II
A.R-12	**1.**Trichlorotrifluroethane (CCl_2FCClF_2)
B.R-22	**2.**Difluoro monochloro methane (CHF_2Cl)
C.R-717	**3.**Ammonia (NH_3)
D.R-113	**4.**Difluoro dichloro methane (CCl_2F_2)

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

IES-10. Ans. (b)

Secondary Refrigerants

IES-11. 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

IES-11. Ans. (d) Practically all refrigerants, except CO_2 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.

IES-12. In milk chilling plants, the usual secondary refrigerant is: [IES-1998]

(a)Ammonia solution (b)Sodium silicate
(c)Propylene glycol (d)Brine

IES-12. Ans. (d)

IES-13. 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

IES-13. Ans. (b)

IES-14. Match List-I with List-II and select the correct answer [IES-1994]

	List-I		List-II
A.	Freon 12	**1.**	Centrifugal systems
B.	Freon 22	**2.**	Low temperature cold storage
C.	Freon 11	**3.**	Window type a/c units
D.	Ammonia	**4.**	Ice plants

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

IES-14. Ans. (a)

Azeotropic Mixtures

IES-15. What is an azeotrope? [IES-2008]

(a) A non-halogenic refrigerant
(b) A refrigerant dissolved in alcohol
(c) A mixture of refrigerants without phase separation
(d) An eco-friendly refrigerant

IES-15. Ans. (c) Azeotrope is a mixture of refrigerants without phase separation.

IES-16. 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

IES-16. Ans. (d)

IES-17. Which one of the following is the fluid whose properties in all its three phase are made use of in thermodynamics? [IES-2007]

(a) Ammonia (b) Freon 12 (c) Helium (d) Water

IES-17. Ans. (d)

IES-18. Oil separator is NOT required in refrigeration system if: [IES-2003]

(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.

IES-18. Ans. (b)

IES-19. Consider the following statements: [IES-1996]
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

IES-19. Ans. (b)

IES-20. Consider the following statements: [IES-1996]

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.

IES-20. Ans. (a) All the statements about effect of moisture on refrigerant are correct.

IES-21. The leaks in a refrigeration system freon are detected by: [IES-2006]
(a) A halide torch, which on detecting produces greenish flame lighting
(b) Sulphur sticks, which on detecting give white smoke
(c) Using reagents
(d) Sensing reduction in pressures

IES-21. Ans. (a) Several methods are available for the detection of leaks. The most common is the ***soap-bubble method.*** The other is the ***halide torch method*** used with fluorocarbons.

Previous 20-Years IAS Questions

IAS-1. Assertion (A): R-22 is used as a refrigerant in all refrigerators.
Reason (R): R-22 is non-toxic and non-inflammable.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-1. Ans. (d)

Designation of Refrigerants

IAS-2. Match List-I (Chemical formula of refrigerant) with List-II (Numerical Designation) and select the correct answer using the codes given below the lists: [IAS-2002]

List-I		**List-II**
A.	NH_3	**1.** 12
B.	CCl_2F_2	**2.** 22
C.	$CHClF_2$	**3.** 40
D.	$CCl_2\,FCCl\,F_2$	**4.** 113
		5. 717

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

IAS-2. Ans. (d) $R(C-1)(H+1)F$ and Cl by balance and for inorganic refrigerant R(700 + Molecular weight).

IAS-3. Match List-I with List-II and select the correct answer using the codes given below the lists: [IAS-2001]

List-I		**List-II**
A.	Refrigerant 11	**1.** $CC1_2F_2$
B.	Refrigerant 12	**2.** $C_2Cl_2F_4$
C.	Refrigerant 22	**3.** CCl_3F
D.	Refrigerant 114	**4.** $CHClF_2$

					5. CH_2ClF				
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

IAS-3. Ans. (c) $R(C-1)(H+1)F$

$\therefore \quad R11 = R011 \Rightarrow C = 1, H = 0, F = 1, Cl = 3$

$\therefore \quad R12 = R012 \Rightarrow C = 1, H = 0, F = 2, Cl = 2$

$\therefore \quad R22 = R022 \Rightarrow C = 1, H = 1, F = 2, Cl = 1$

$\therefore \quad R114 = R114 \Rightarrow C = 2, H = 0, F = 4, Cl = 2$

IAS-4. The refrigerant – 12 (R – 12) used in vapour compression refrigeration system is: [IAS-2000]

(a) $CHClF_2$ (b) CCl_2F_2 (c) $CHCl_2F$ (d) $CClF_3$

IAS-4. Ans. (b) R12 = R012 = $R(C-1)(H+1)F$. Therefore $C = 1$, $H = 0$, $F = 2$ by balance Cl = 2

IAS-5. Match List-I (Refrigerant) with List-II (Designation) and select the correct answer using the codes given below the lists: [IAS-1999]

List-I	**List-II**
A. Dichlorodifluoromethane	**1.** R 718
B. Water	**2.** R 22
C. Methyl chloride	**3.** R40
D. Monochloride-fluoromethane	**4.** R 12

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

IAS-5. Ans. (d)

Secondary Refrigerants

IAS-6. 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.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-6. Ans. (a)

IAS-7. The pipes and fitting in an ammonia refrigeration system should be made of: [IAS-1998]

(a) Cast steel or wrought iron (b) Aluminium
(c) Naval brass (d) Copper

IAS-7. Ans. (a)

Azeotropic Mixtures

IAS-8. Match List-I with List-II and select the correct answer using the codes given below the lists: [IAS-2004]

List-I	**List-II**
A. Sulphur candle test	**1.** Propane
B. Halide torch test	**2.** Ammonia

C.Soap and water test | **3.**Halocarbon refrigerants
D.Ammonia swab test | **4.**Sulphur dioxide

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

IAS-8. Ans. (a)

IAS-9. 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

IAS-9. Ans. (c)

IAS-10. Which one of the following refrigerants has the highest critical temperature? [IAS-1996]
(a) Water (b) Carbon dioxide (c) Freon 12 (d) Ammonia

IAS-10. Ans. (a)

IAS-11. The significant advantage of using ammonia as a refrigerant is its
(a)Characteristic odour (b)High latent heat **[IAS-1996]**
(c)Solubility (d)Inflammability

IAS-11. Ans. (b)

IAS-12. The color of the flame of halide torch, in a case of leakage of Freon refrigerant, will change to: [IAS-1996]
(a) Bright green (b) Yellow (c) Red (d) Orange

IAS-12. Ans. (a)

IAS-13. Ideal refrigeration mixture is one which [IAS-2007]
(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

IAS-13. Ans. (c)

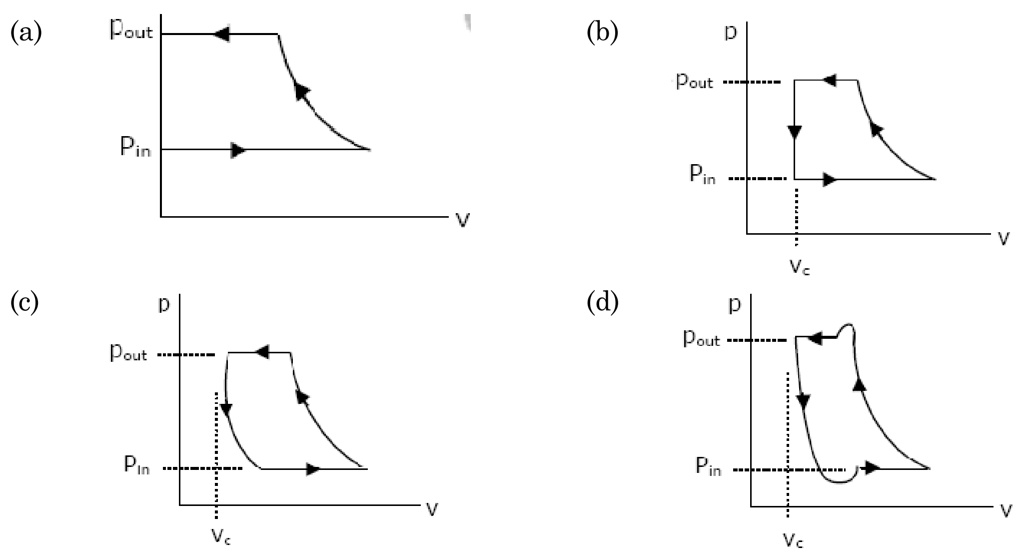
4. Refrigerant Compressors

OBJECTIVE QUESTIONS (GATE, IES, IAS)

Previous 20-Years GATE Questions

Types of Compressors

GATE-1. p–v diagram has been obtained from a test on a reciprocating compressor. Which of the following represents that diagram? [GATE-2005]



GATE-1. Ans. (d) It is obtained from a test, so p_{out} will be some less than compressor outlet pressure for opening the delivery valve.

GATE-2. A single-acting two-stage compressor with complete inter cooling delivers air at 16 bar. Assuming an intake state of 1 bar at 15°C, the pressure ratio per stage is: [GATE-2001]

(a) 16 (b) 8 (c) 4 (d) 2

GATE-2. Ans. (c) Pressure ratio of each stage must be same

$$r_p = \frac{p_i}{p_1} = \frac{p_2}{p_i} = \sqrt{\frac{p_i \times p_2}{p_1 \times p_i}} = \sqrt{\frac{p_2}{p_1}} = \sqrt{16} = 4$$

GATE-3. Air (C_p = 1 kJ/kg, γ = 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: [GATE-1998]

(a)160 (b)172 (c)182 (d)225

GATE-3. Ans. (c) $W_{ideal} = \frac{\gamma RT_1}{\gamma - 1}\left[\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] = c_p T_1\left[\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] = 1 \times 300\left[4^{\frac{1.4-1}{1.4}} - 1\right] = 146\,kJ/kg$

$W_{actual} = \frac{W_{ideal}}{\eta} = \frac{146}{0.8} = 182\,kJ/kg$

GATE-4. Consider a two stage reciprocating air compressor with a perfect intercooler operating at the best intermediate pressure. Air enters the low pressure cylinder at 1bar, 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 J/kg K, the work done per kg air in the high pressure cylinder is: [GATE-1997]

(a) 111 kJ (b) 222 kJ (c) 37 kJ (d) 74 kJ

GATE-4. Ans. (a) Pressure ratio must be same

$\therefore\ r_P = \frac{P_i}{P_1} = \frac{P_2}{P_i} = \sqrt{\frac{P_i \times P_2}{P_1 \times P_i}} = \sqrt{\frac{P_2}{P_1}} = \sqrt{\frac{9}{1}} = 3$

Work done of each stage also same

$W_{each\ stage} = \frac{\gamma RT_1}{\gamma - 1}\left[r_P^{\frac{\gamma-1}{\gamma}} - 1\right] = \frac{1.4 \times 287 \times 300}{(1.4-1)}\left[3^{\frac{1.4-1}{1.4}} - 1\right] = 111\,kJ$

GATE-5. A refrigeration compressor designed to operate with R 22………. (can/cannot) be operated with R 12 because the condensing pressure of R22 at any give temperature is……..(higher/lower) than that of R 12. [GATE-1992]

(a) Cannot; Higher (b) Can; Higher
(c) Cannot; Lower (d) Can; Lower

GATE-5. Ans. (a)

GATE-6. 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]**

	List-I		List-II
1.	Inter-cooling	**A.**	No heat transfer during compression
2.	Isothermal compression	**B.**	Reduces low pressure compressor work
		C.	Heat rejection during compression
		D.	Reduces high pressure compressor work

GATE-6. Ans. (c, d)

Volumetric Efficiency of reciprocating Compressors

GATE-7. 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

GATE-7. Ans. (a)

Effect of Clearance on Work

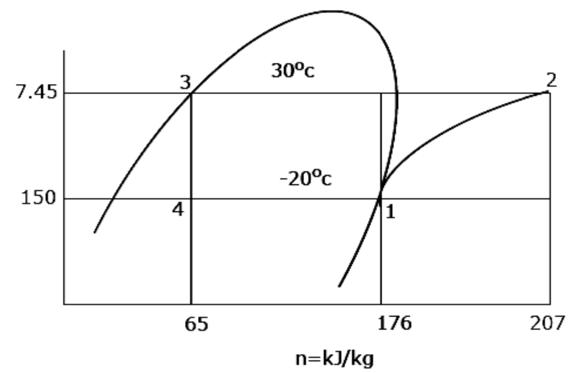
GATE-8. Clearance volume of a reciprocating compressor is 100 ml, and the volume of the cylinder at bottom dead centre is 1.0 litre. The clearance ratio of the compressor is: [GATE-1997]

(a) $\frac{1}{11}$ (b) $\frac{1}{10}$ (c) $\frac{1}{9}$ (d) $\frac{1}{12}$

GATE-8. Ans. (c) Piston displacement volume = 900 ml

Therefore clearance ratio = $\frac{\text{Clerance volume}}{\text{Piston displacement volume}} = \frac{100}{900} = \frac{1}{9}$

GATE-9. 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



[GATE-2004]

states are given in the figure. To realize 2 Tons of refrigeration, the actual volume displacement rate considering the effect of clearance is:

(a) 6.35×10^{-3} m³/s (b) 63.5×10^{-3} m³/s (c) 635×10^{-3} m³/s (d) 4.88×10^{-3} m³/s

GATE-9. Ans. (a) Given, Clearance volume ration, $C = 0.03$

Specific volume at suction, $v_1 = 0.1089$ m³/kg

Net refrigerating effect = 2 ton = 2 × 3.516 kJ = 7.032 kJ/s

Specific heat ratio, $c = 1.15$

∴ Volume = $0.063 \times 0.1089 = 6.89 \times 10^{-3}$ m³/s

Volumetric efficiency = $1 + C - C\left(\frac{p_2}{p_1}\right)^{v_e} = 1 + 0.03 - 0.03\left(\frac{7.45}{1.50}\right)^{\frac{1}{1.15}} = 0.909$

∴ Volume displacement rate considering effect of clearance

$= 6.89 \times 10^{-3} \times 0.909 = 6.26 \times 10^{-3}$ m³/s

Centrifugal Compressors

GATE-10. The specific speed of a centrifugal compressor is generally [GATE-1997]

(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

GATE-10. Ans. (d)

Performance Characteristics of Centrifugal Compressors

GATE-11. Air (C_p = 1 KJ, γ = 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: [GATE-1998]

(a) 160 (b) 172 (c) 182 (d) 225

GATE-11. Ans. (c) $W_{ideal} = \frac{\gamma}{\gamma-1}(P_1V_1 - P_2V_2) = \frac{\gamma}{\gamma-1} P_1V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{(\gamma-1)}{\gamma}} - 1\right]$

$$= \frac{\gamma}{\gamma-1} RT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{(\gamma-1)}{\gamma}} - 1\right] = C_pT_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{(\gamma-1)}{\gamma}} - 1\right] = 1 \times 300[4^{0.4/1.4}-1] = 146$$

$$\therefore \quad W_{actual} = \frac{W_{ideal}}{\eta} = \frac{146}{0.8} = 182$$

Previous 20-Years IES Questions

Types of Compressors

IES-1. A centrifugal compressor is suitable for which of the following? ` [IES-2008]

(a) High pressure ratio, low mass flow
(b) Low pressure ratio, low mass flow
(c) High pressure ratio, high mass flow
(d) Low pressure ratio, high mass flow

IES-1. Ans. (d)

IES-2. Match List-I (Name of equipment) with List-II (Pressure ratio) and select the correct answer using the code given below the lists: [IES-2007]

List-I	List-II
A. Fan	**1.** 1.1
B. Blower	**2.** 2.5
C. Centrifugal air compressor	**3.** 4
D. Axial flow air compressor	**4.** 10

Codes:	**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

IES-2. Ans. (b)

IES-3. Which of the following can be the cause/causes of an air-cooled compressor getting overheated during operation? [IES-2006]

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

IES-3. Ans. (d)

IES-4. Which type of valves is generally used in reciprocating refrigerant compressors? [IES-2006]

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

IES-4. Ans. (c)

IES-5. Reciprocating compressors are provided with [IES-2000]
(a) Simple disc/plate valve (b) Poppet valve
(c) Spring-loaded disc valve (d) Solenoid valve

IES-5. Ans. (a)

IES-6. Which one of the following statements is correct? [IES-2004]
In reciprocating compressors, one should aim at compressing the air
(a) Adiabatically (b) Isentropically (c) Isothermally (d) Poly tropically

IES-6. Ans. (c)

IES-7. Roots blower is an example of: [IES-2003]
(a) Reciprocating (positive displacement) compressor
(b) Rotary (positive displacement) compressor
(c) Centrifugal compressor
(d) Axial compressor

IES-7. Ans. (b)

IES-8. Match List-I (Refrigeration equipment) with List-II (Characteristic) and select the correct answer: [IES-2002]

List-I	List-II
A. Hermetically sealed compressor	**1.** Capillary tube
B. Semi-hermitically sealed	**2.** Both compressor and motor enclosed Compressor in a shell or casting
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

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

IES-8. Ans. (b)

IES-9. The capacity of an air compressor is specified as 3 m^3/min. It means that the compressor is capable of: [IES-2000]
(a) Supplying 3 m^3 of compressed air per minute
(b) Compressing 3 m^3 of free air per minute
(c) Supplying 3 m^3 of compressed air at NTP
(d) Compressing 3 m^3 of standard air per minute

IES-9. Ans. (b)

IES-10. Which one of the following pairs of features and compressors type is NOT correctly matched? [IES-2000]
(a) Intake and delivery ports : Vane compressor back flow and internal compression is attained by compression cylindrical rotor set to eccentric casing
(b) Intermittent discharge : Reciprocating compressor pressure, slow requires receiver, produces high speed and lubrication
(c) Continuous flow, radial now, problems

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

IES-10. Ans. (c)

IES-11. 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
IES-11. Ans. (d)

IES-12. 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".
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
IES-12. Ans. (b)

IES-13. 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?
(a) $(p_s + p_d)/2$ (b) $(p_s + p_d)/2$ (c) $(p_s \times p_d)^{1/2}$ (d) $(p_s + p_d)^{1/4}$ **[IES-2006]**
IES-13. Ans. (c)

IES-14. When are shock waves formed in air compressors? [IES-2006]
(a) Mach number < 0.9
(b) Mach number > 0·9
(c) Mach number = 2
(d) Mach number changes suddenly from one value to another
IES-14. Ans. (b)

IES-15. Assertion (A): In multi-stage compressors, the polytropic efficiency is always greater than the isentropic efficiency. [IES-2005]
Reason(R): Higher the pressure ration, the greater is the polytropic efficiency.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
IES-15. Ans. (b)

IES-16. 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? [IES-2004]
(a) 6 bar (b) 9 bar (c) 27.75 bar (d) $9/\sqrt{2}$ bar
IES-16. Ans. (b) $P_i = \sqrt{P_1 P_2} = \sqrt{54 \times 1.5} = 9$ bar

IES-17. During steady flow compression process of a gas with mass flow rate of 2 kg/s. increase in specific enthalpy is 15kJ/kg and decrease in kinetic energy is 2 kJ/kg. The rate of heat rejection to the environment is 3kW. The power needed to drive the compressor is: [IES-2003]

(a) 23 kW (b) 26kW (c) 29kW (d) 37 kW

IES-17. 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

IES-18. 0.70 kg/s of air enters with a specific enthalpy of 290 kJ and leaves it with 450 kJ of specific enthalpy. Velocities at inlet and exit are 6 m/s and 2 m/s respectively. Assuming adiabatic process, what is power input to the compressor? [IES-2009]

(a) 120 kW (b) 118 kW (c) 115kW (d) 112 kW

IES-18. Ans. (d) Power input to compressor $= m\left[\left(h_2 + \frac{V_2^2}{2g}\right) - \left(h_2 + \frac{V_1^2}{2g}\right)\right]$

$$= 0.7\left[\left(450 + \frac{2^2}{2\times 9.8\times 100}\right) - \left(290 + \frac{6^2}{2\times 9.8\times 1000}\right)\right] = 112\,\text{kW}$$

IES-19. 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) $p_i = p_c / p_e$

IES-19. Ans. (b)

IES-20. 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 [IES-2003]

(a) Decreases continuously (b) Increases continuously
(c) Remains constant (d) Increases and then decreases

IES-20. Ans. (b)

IES-21. 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 inter-cooling, the expression for the total work of three stage is: [IES-2001]

(a) $\frac{3n}{(n-1)} p_1 v_1 \left\{\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right\}$ (b) $\frac{n}{(n-1)} p_1 v_1 \left\{\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{3n}} - 1\right\}$

(c) $\frac{n}{(n-1)} p_1 v_1 \left\{\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right\}$ (d) $\frac{3n}{(n-1)} p_1 v_1 \left\{\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{3n}} - 1\right\}$

IES-21. Ans. (d)

IES-22. 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 40 kJ/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

IES-22. Ans. (c)

IES-23. 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

IES-23. 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 $P_i = \sqrt{P_1 \quad P_2} = \sqrt{1.1 \quad \times \quad 20} = \sqrt{22} = 4.7$ bar

IES-24. The discharge pressure of the compressor in the refrigeration system goes up due to the [IES-2000]

(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-24. Ans. (a)

IES-25. 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

IES-25. Ans. (d) For minimum work of compression in 3 stage compressor the delivery pressure of 1st stage is $\sqrt[3]{27/1} = 3\,\text{bar}$ = 3 bar

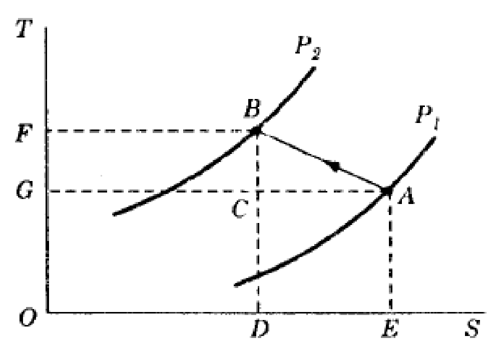
IES-26. Which one of the following statements is true? [IES-1998]

(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

IES-26. Ans. (c)

IES-27. 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



[IES-1997]

IES-27. Ans. (b) Heat rejection during AB is given by area below it on entropy axis, i.e. ABDE. DES

IES-28. For a multistage compressor, the polytropic efficiency is: [IES-1996]

(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

IES-28. Ans. (a) For multistage compressor, the polytropic efficiency is the efficiency of all stages combined together.

IES-29. Phenomenon of choking in compressor means [IES-1996]
(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.

IES-29. Ans. (b) Phenomenon of choking in compressor means fixed mass flow rate regardless of pressure ratio.

IES-30. The usual assumption in elementary compressor cascade theory is that
(a) Axial velocity through the cascade changes. **[IES-1996]**
(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.

IES-30. Ans. (c) The usual assumption in elementary compressor cascade theory is that axial velocity thr6ugh the cascade does not change.

IES-31. In a reciprocating air compressor the compression works per kg of air.
(a) Increases as clearance volume increases **[IES-1995]**
(b) Decreases as clearance volume increases
(c) Is independent of clearance volume
(d) Increases with clearance volume only for multistage compressor.

IES-31. Ans. (a) Compression work per kg. of air increases as clearance volume increases.

IES-32. Assertion (A): The isothermal efficiency of a reciprocating compressor becomes 100% if perfect cooling of the fluid during compression is attained. **[IES-1993]**
Reason (R): Work done in a reciprocating compressor is less if the process of compression is isothermal rather than polytropic.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-32. Ans. (a) Both assertion and reason are correct and R provides correct explanation for A.

IES-33. Consider the following statements: [IES-1993]
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

IES-33. Ans. (b)

IES-34. 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: [IES-1992]

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

IES-34. Ans. (a)

IES-35. The suction pressure is 1 bar and delivery pressure is 125 bar. What is the ideal intermediate pressure at the end of first stage for a 3-stage air compressor? [IES-2008]

(a) 25 bar (b) 5 bar (c) 10 bar (d) 20 bar

IES-35. Ans. (b)

IES-36. For an air-conditioning plant above 300 ton, which one of the following systems would normally be preferred? [IES-1997]

(a) Ammonia reciprocating compressor (b) Centrifugal chiller
(c) Absorption refrigeration system (d) Hermetic compressor

IES-36. Ans. (b)

IES-37. When the discharge pressure is too high in a refrigeration system, high pressure control is installed to: [IES-1996]

(a) Stop the cooling fan (b) Stop the water circulating pump.
(c) Regulate the flow of cooling water (d) Stop the compressor.

IES-37. Ans. (d)

IES-38. 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:

(a) $P_i= P_2-P_1$ (b) $P_i=\frac{1}{2}(P_1+P_2)$ **[IES-2003, IES-1996]**
(c) $P_i=\sqrt{P_1 \quad P_2}$ (d) $P_i=\sqrt{P_2^2 \quad - \quad P_1^2}$

IES-38. Ans. (c). We know that for minimum compressor work pressure ratio of both stage must be same so $\frac{P_1}{P_i}=\frac{P_i}{P_2}$ or $P_i=\sqrt{P_1 \quad P_2}$

IES-39. 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) $P_i=\sqrt{P_1 \quad P_2}$ (d) $P_i=\sqrt{P_2^2 \quad - \quad P_1^2}$

IES-39. Ans. (c). 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 $P_i=\sqrt{P_1 \quad P_2}$

Note: Here Pa is superfluous data that has no use.

IES-40. 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: [IES-1999]
(a) 14 bar (b) 9 bar (c) 5.196 bar (d) 3 bar

IES-40. Ans. (d). We know that for minimum compressor work pressure ratio of 3-stage must be same so $\frac{P_{i1}}{P_1} = \frac{P_{i2}}{P_{i1}} = \frac{P_2}{P_{i2}} = \sqrt[3]{\frac{P_{i1}}{P_1}\frac{P_{i2}}{P_{i1}}\frac{P_2}{P_{i2}}} = \sqrt[3]{\frac{P_2}{P_1}}$

or $P_{i1} = P_1 \times \sqrt[3]{\frac{P_2}{P_1}} = P_1^{2/3}.P_2^{1/3} = 1 \times 27^{1/3} = 3$ bar

IES-41. 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: [IES-1993]
(a) $(P_1P_4)^{1/3}$ and $(P_1P_4)^{2/3}$ (b) $(P_1^2 P_4)^{1/3}$ and $(P_1P_4^2)^{1/3}$
(c) $(P_1P_4)^{1/2}$ and $P_1P_4^{2/3}$ (d) $(P_1P_4)^{1/2}$ and $(P_1P_4)^{2/3}$

IES-41. Ans. (b) We know that for minimum compressor work pressure ratio of 3-stage must be same so $= \frac{P_2}{P_1} = \frac{P_3}{P_2} = \frac{P_4}{P_3} = \sqrt[3]{\frac{P_2}{P_1}\frac{P_3}{P_2}\frac{P_4}{P_3}} = \sqrt[3]{\frac{P_4}{P_1}}$

or $P_2 = P_1 \times \sqrt[3]{\frac{P_4}{P_1}} = (P_1^2 P_4)^{1/3}$ and $P_3 = \frac{P_4}{\sqrt[3]{\frac{P_4}{P_1}}} = (P_1P_4^2)^{1/3}$

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

IES-42. 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: [IES-1998]
(a) 6 bar (b) 8 bar (c) 10 bar (d) 12 bar

IES-42. Ans. (b): We know that for minimum compressor work pressure ratio of 4-stage must be same so $\frac{P_{i1}}{P_1} = \frac{P_{i2}}{P_{i1}} = \frac{P_{i3}}{P_{i2}} = \frac{P_2}{P_{i3}} = \sqrt[4]{\frac{P_{i1}}{P_1}\frac{P_{i2}}{P_{i1}}\frac{P_{i3}}{P_{i2}}\frac{P_2}{P_{i3}}} = \sqrt[4]{\frac{P_2}{P_1}}$

or $P_{i3} = \frac{P_2}{\sqrt[4]{\frac{P_2}{P_1}}} = P_1^{1/4}P_2^{3/4} = 1^{1/4}\text{x}(16)^{3/4} = 8$ bar

Volumetric Efficiency of reciprocating Compressors

IES-43. Which one of the following statements is correct for reciprocating air compressor? [IES-2007]
(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-43. Ans. (d) $\eta_v = 1 + C - C.\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$

IES-44. Consider the following statements: [IES-2006]
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-44. Ans. (b) $\eta_v = 1 + C - C\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$ $if\ p_2 \downarrow then\,\eta_v \uparrow$

IES-45. Which of the following statements are correct for multi staging in a reciprocating air compressor? [IES-2006]
1.It decreases the volumetric efficiency.
2.The work done can be reduced.
3. 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-45. Ans. (b) 1 is false, it increases the volumetric efficiency.

IES-46. Consider the following statements [IES-2000]
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-46. Ans. (c)

IES-47. 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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-47. Ans. (a)

IES-48. 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%

IES-48. Ans. (a)

IES-49. The bore and stroke of the cylinder of a 6-cylinder engine working on an Otto-cycle are 17 cm and 30 cm respectively, total clearance volume is 9225 cm³, then what is the compression ratio? [IES-2009]

(a) 7.8 (b) 6.2 (c) 15.8 (d) 5.4

IES-49. Ans. (d) Clearance volume of a single cylinder $= \frac{9225}{6} = 1537.5 \text{ cm}^3$

Swept volume $= V_S = \frac{\pi}{4} d^2 L = \frac{\pi}{4} \times (17^2) \times 30 = 6805.95 \text{ cm}^3$

Compression ratio $= 1 + \frac{V_S}{V_C} = 1 + \frac{6805.95}{1537.50} = 5.42$

IES-50. 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

IES-50. Ans. (d) The volumetric efficiency of a compressor depends upon
1. Clearance volume 2. Pressure ratio 3. Index of expansion

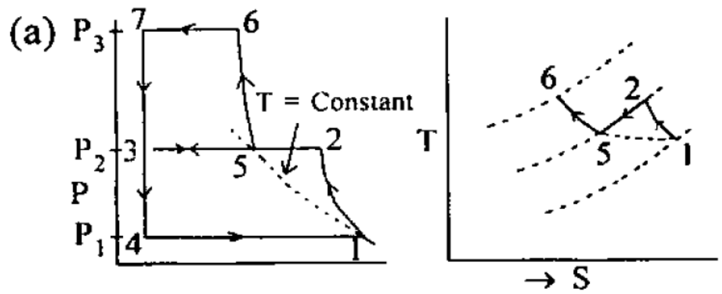
IES-51. A gas engine has a swept volume of 300 cc and clearance volume of 25 cc. Its volumetric efficiency is 0.88 and mechanical efficiency is 0.90. What is the volume of the mixture taken in per stroke? [IES-1995]

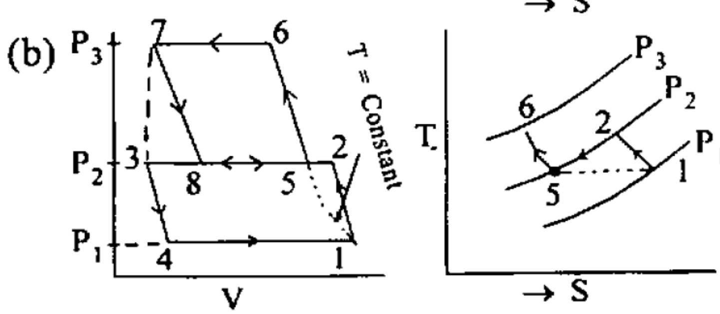
(a) 248 cc (b) 252 cc (c) 264 cc (d) 286 cc

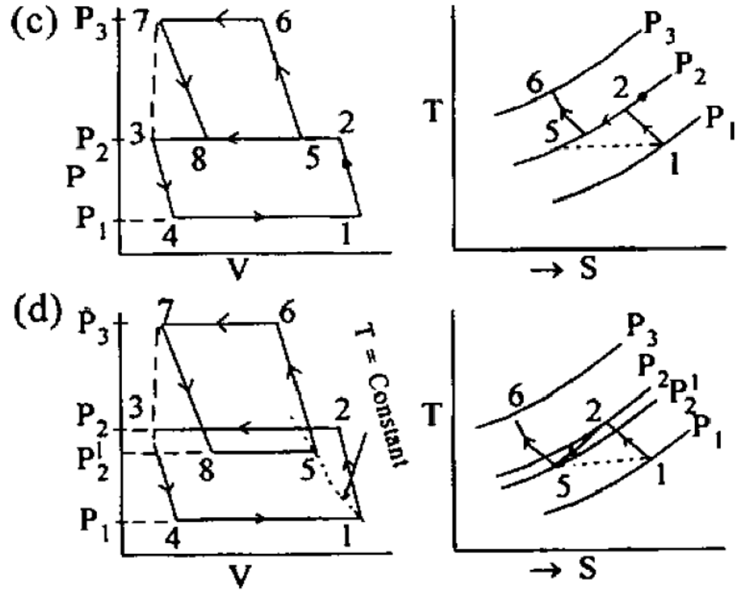
IES-51. Ans. (c) Volumetric $\eta = \frac{\text{Volume of mixture}}{300}$, and

Volume of mixture = 300 × 0.88 = 264 cc

IES-52. Which one of the following graphs shows the correct representation of the processes for a two stage air compressor with perfect intercooling and no pressure drop in the intercooler? [IES-2009]







IES-52. Ans. (b)

Effect of Clearance on Work

IES-53. 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 **[IES-1995]**

IES-53. Ans. (a)

Performance Characteristics of Reciprocating Compressors

IES-54. Which of the following techniques are employed for control of reciprocating compressors? [IES-2007]
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

IES-54. Ans. (d)

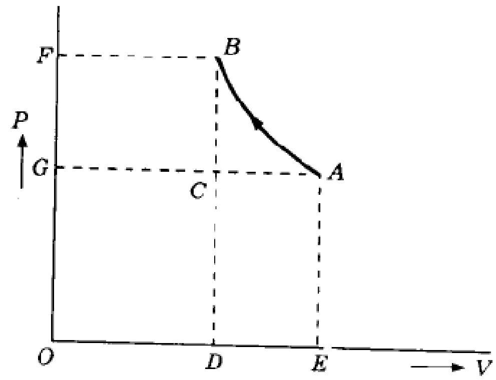
IES-55. Consider the following factors: [IES-1999]
1. Cylinder size 2. Clearance ratio
3. Delivery pressure 4. Compressor shaft power
The factors which affect the volumetric efficiency of a single-stage reciprocating air compressor would include
(c) 1 and 2 (b) 3 and 4 (c) 2 and 3 (d) 1 and 4

IES-55. Ans. (a) Volumetric efficiency of a single stage reciprocating air compressor is

$\eta_v = 1 + C - C.\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}$ dependent on clearance ratio and delivery pressure.

IES-56. 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



[IES-1999]

IES-56. Ans. (c)

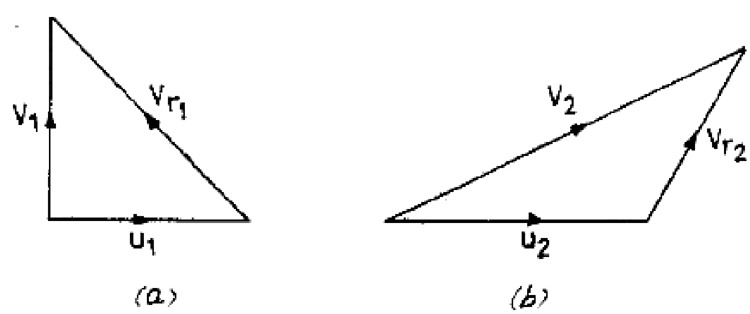
Rotary Compressors

IES-57. Assertion (A): A vane type rotary compressor is a roto-dynamic machine. Reason(R): A roto-dynamic machine is one in which a fluid flows freely through the rotating part of the machine. [IES-2005]

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-57. Ans. (a)

IES-58. The inlet and exit velocity diagrams of a turbomachine rotor are shown in the given figure. The turbo-machine is: [IES-2002; 1993]



(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

IES-58. 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_{r2} is in the direction of u_2 which means blades are forward curved. In case of backward curved blades the direction of V_{r2} will be opposite to that of u_2 i.e. angle between V_{r2} & u_2 will be acute.

Centrifugal Compressors

IES-59. In the centrifugal air compressor design practice, the value of polytropic exponent of compression is generally taken as [IES-1998]

(a) 1.2 (b) 1.3 (c) 1.4 (d) 1.5

IES-59. Ans. (c)

IES-60. What does application of centrifugal air compressors lead to? **[IES-2006]**
(a) Large frontal area of aircraft
(b) Higher flow rate through the engine
(c) Higher aircraft speed
(d) Lower frontal area of the aircraft

IES-60. Ans. (a)

IES-61. In a centrifugal compressor, how can the pressure ratio be increased? **[IES-2006]**
(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

IES-61. Ans. (c)

IES-62. The pressure rise in the impeller of centrifugal compressor is achieved by: **[IES-200**
(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

IES-62. Ans. (c)

IES-63. The flow in the vane less space between the impeller exit and diffuser inlet of a centrifugal compressor can be assumed as **[IES-2001]**
(a) Free vortex (b) Forced vortex
(c) Solid body rotation (d) Logarithmic spiral

IES-63. Ans. (d)

IES-64. Consider the following statements **[IES-2000]**
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 10 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

IES-64. Ans. (b)

IES-65. 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? **[IES-2005]**
(a) 36 kJ (b) 72 kJ (c) 144kJ (d) 360 kJ

IES-65. Ans. (c)

IES-66. In centrifugal compressor terminology, vane less space refers to the space between **[IES-1999]**
(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

IES-66. Ans. (d)

IES-67. 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: [IES-1997]
(a) Low pressure ratio (b) Limitation of size of receiver
(c) Large speeds (d) High compression index

IES-67. Ans. (a) Pressure ratio is low for centrifugal compressors

IES-68. Given: V_{w2} = velocity of whirl at outlet [IES-1997]
u_2 = peripheral velocity of the blade tips
The degree of reaction in a centrifugal compressor is equal to:
$(a) 1-\frac{V_{w2}}{2u_2}$ $(b) 1-\frac{u_2}{2V_{w2}}$ $(c) 1-\frac{2V_{w2}}{u_2}$ $(d) 1-\frac{V_{w2}}{u_2}$

IES-68. Ans. (a)

IES-69. For large tonnage (more than 200 tons) air-conditioning applications, which one of the following types of compressors is recommended? [IES-1996]
(a) Reciprocating (b) Rotating (c) Centrifugal (d) Screw

IES-69. Ans. (d) For large tonnage air conditioning applications, specially built centrifugal compressors are used.

IES-70. In a centrifugal compressor assuming the same overall dimensions, blade inlet angle and rotational speeds, which of the following bladings will given the maximum pressure rise? [IES-1995]
(a) Forward curved blades
(b) Backward curved blades.
(c) Radial blades
(d) All three types of bladings have the same pressure rise.

IES-70. Ans. (a) Forward curved blades give maximum pressure rise.

IES-71. In a centrifugal compressor, the highest Mach number leading to shockwave in the fluid flow occurs at [IES-1995]
(a) Diffuser inlet radius (b) Diffuser outlet radius
(c) Impeller inlet radius (d) Impeller outer radius

IES-71. Ans. (c)

IES-72. 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 [IES-1994]
(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

IES-72. Ans. (d) Head, discharge and power are proportional to d^2, d and d^3.

IES-73. 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

IES-73. Ans. (a)

IES-74. 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 [IES-1993]
(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

IES-74. 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.

IES-75. Assertion (A): Multistaging compression is done only in reciprocating compressors. [IES-2009]
Reason (R): Reciprocating compressor are used to compress large pressure ratio at low discharge.
(a) Both A and R are individually true and R is the correct explanation of A.
(b) Both A and R are individually true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

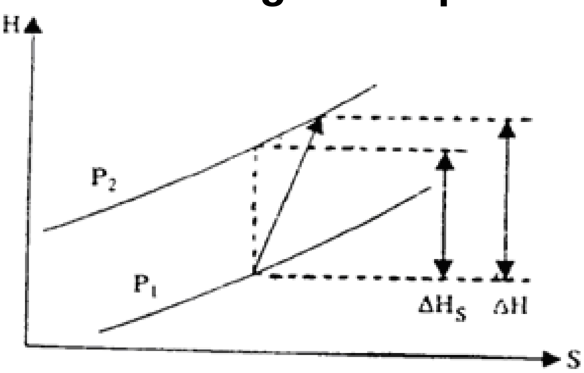
IES-75. Ans. (d) Multi-staging compression is done for both rotary and reciprocating compressors.

IES-76. When the outlet angle from the rotor of a centrifugal compressor is more than 90, then the blades are said to be: [IES-1992]
(a) Forward curved (b) Backward curved
(c) Radial (d) Either backward or forward curved

IES-76. Ans. (a)

Performance Characteristics of Centrifugal Compressors

IES-77. Which one of the following expresses the isentropic efficiency η of the compression process in terms of enthalpy changes as indicated in the figure given above?



(a) $\eta = \dfrac{\Delta H_s}{\Delta H}$

(b) $\eta = \dfrac{\Delta H}{\Delta H_s}$

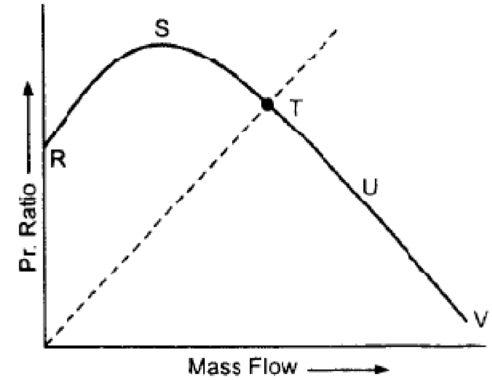
(c) $\eta = \dfrac{(\Delta H - \Delta H_s)}{\Delta H}$

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

[IES-2005]

IES-77. Ans. (a)

IES-78. **Which portion of the centrifugal compressor characteristics shown in the figure is difficult to obtain experimentally?**
(a) RS
(b) ST
(c) TU
(d) UV



[IES-2001]

IES-78. Ans. (a)

IES-79. For centrifugal compressors, which one of the following is the correct relationship between pressure coefficient (ϕ_p) slip factor (ϕ_s) work input factor (ϕ_w) and isentropic efficiency (η_a)? [IES-2005]

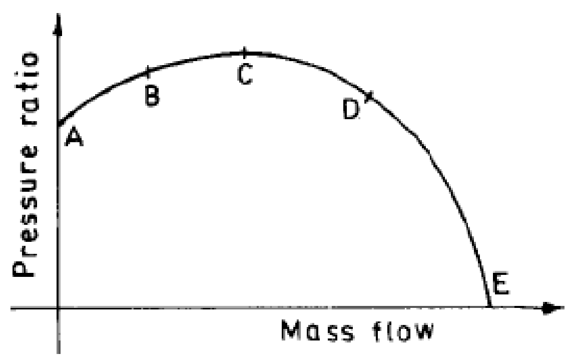
(a) $\phi_p = \dfrac{\phi_s \times \phi_w}{\eta_a}$ (b) $\phi_p = \dfrac{\phi_w}{\phi_s \times \eta_a}$ (c) $\phi_p = \phi_s \times \phi_w \times \eta_a$ (d) $\phi_p = \dfrac{\phi_s \times \eta_a}{\phi_w}$

IES-79. Ans. (c)

IES-80. Which one of the following is the effect of blade shape on performance of a centrifugal compressor? [IES-1996]
(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.

IES-80. Ans. (c) In centrifugal compressor, backward curved blades lead to stable performance.

IES-81. 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



[IES-1995]

IES-81. Ans. (c) Curve B to D represents permissible operating range of compressor.

Axial flow compressor

IES-82. Consider the following statements pertaining to axial flow compressors:
1. **Like centrifugal compressor, axial flow compressors are limited by surge at low mass flow rates. [IES-2009]**
2. **Axial flow compressors experience choking at low flow rates.**
3. **The design point of axial flow compressors is close to the surge limit.**

4. As mass flow diminishes the compressor blades stall causing flow separation.
Which of the above statements is/are correct?
(a) 1 and 2 only (b) 1, 2 and 3 (c) 1, 3 and 4 (d) 3 and 4 only

IES-82. Ans. (d)

IES-83. In an axial flow compressor, when the degree of reaction is 50%, it implies that [IES-2006]
(a) Work done in compression will be the least
(b) 50% stages of the compressor will be ineffective
(c) Pressure after compression will be optimum
(d) The compressor will have symmetrical blades

IES-83. Ans. (d)

IES-84. Consider the following statements: [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

IES-84. Ans. (b)

IES-85. While flowing through the rotor blades in an axial flow air compressor, the relative velocity of air: [IES-2005]
(a) Continuously decreases (b) Continuously increases
(c) First increases and then decreases (d) First decreases and then increases

IES-85. Ans. (a)

IES-86. What is the ratio of the static enthalpy rise in the rotor to the static enthalpy rise in the stage of an axial flow compressor defined as?
(a) Power input factor (b) Flow coefficient **[IES-2008]**
(c) Temperature coefficient (d) Degree of reaction

IES-86. Ans. (d) Degree of Reaction: A certain amount of distribution of pressure (a rise in static pressure) takes place as the air passes through the rotor as well as the stator; the rise in pressure through the stage is in general, attributed to both the blade rows. The term degree of reaction is a measure of the extent to which the rotor itself contributes to the increase in the static head of fluid. It is defined as the ratio of the static enthalpy rise in the rotor to that in the whole stage. Variation of over the relevant temperature range will be negligibly small and hence this ratio of enthalpy rise will be equal to the corresponding temperature rise.

IES-87. Which one of the following is the correct expression for the degree of reaction for an axial-flow air compressor? [IES-2004]
(a) $\dfrac{\text{Work input to the rotor}}{\text{Work input to the stage}}$ (b) $\dfrac{\text{Change of enthalpy in the rotor}}{\text{Change of enthalpy in the stage}}$
(c) $\dfrac{\text{Pressure rise in the rotor}}{\text{Pressure rise in the stage}}$ (d) $\dfrac{\text{Isentropic work}}{\text{Actual work}}$

IES-87. Ans. (b) Degree of reaction,

$$R = \frac{\text{Enthalpy rise in rotor}}{\text{Enthalpy rise in the stage}} = \frac{h_1 - h_0}{h_2 - h_0} = \frac{V_{r_1}^2 - V_{r_2}^2}{2V_b \Delta V_w}$$

By re-arrangement,

$$R = \frac{V_f^2(\sec^2\beta_1 - \sec^2\beta_2)}{2V_b V_f(\tan\beta_1 - \tan\beta_2)} = \frac{V_f}{2V_b}(\tan\beta_1 + \tan\beta_2)$$

IES-88. If the static temperature rise in the rotor and stator respectively are ΔT_A and ΔT_B, the degree of reaction in an axial flow compressor is given by:

(a) $\frac{\Delta T_A}{\Delta T_B}$ (b) $\frac{\Delta T_A}{\Delta T_A + \Delta T_B}$ (c) $\frac{\Delta T_B}{\Delta T_A + \Delta T_B}$ (d) $\frac{\Delta T_B}{\Delta T_A}$ **[IES-1999]**

IES-88. Ans. (b) $\text{Degree of reaction of axial flow compressor} = \frac{\text{Static temperature rise in rotor}}{\text{Static temperature rise in stage}}$

$$= \frac{\Delta T_A}{\Delta T_A + \Delta T_B}$$

IES-89. Degree of reaction in an axial compressor is defined as the ratio of static enthalpy rise in the **[IES-1996]**

(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

IES-89. Ans. (c) Degree of reaction in an axial compressor is defined as the ratio of static enthalpy rise in the rotor to static enthalpy rise in the stage.

IES-90. Compared to axial compressors centrifugal compressors are more suitable for **[IES-2002]**

(a) High head, low flow rate (b) Low head, low flow rate
(c) Low head, high flow rate (d) High head, high flow rate

IES-90. Ans. (c)

IES-91. Stalling of blades in axial- flow compressor is the phenomenon of:

(a) Air stream blocking the passage **[IES-2002]**
(b) Motion of air at sonic velocity
(c) Unsteady, periodic and reversed flow
(d) Air steam not able to follow the blade contour

IES-91. Ans. (d) Same Q. **[IES-2007]**

IES-92. In an axial flow compressor **[IES-2002]**

α_1 =exit angle from stator **β_1 = inlet angle to rotor**
α_2 = inlet angle to stator **β_2 = outlet angle from rotor**
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 $\beta_1 = \beta_2$

IES-92. Ans. (c)

IES-93. 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? **[IES-2000]**

(a) Incidence angle of the approaching air is measured from the trailing edge of the blade

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

IES-93. Ans. (c)

IES-94. The turbo machine used to circulate refrigerant in a large refrigeration plant is: [IES-1998]
(a) A centrifugal compressor (b) A radial turbine
(c) An axial compressor (d) An axial turbine

IES-94. Ans. (a)

IES-95. The energy transfer process is: [IES-1998]
(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

IES-95. Ans. (b)

IES-96. 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: [IES-199
(a) 1.00 (b) 0.75 (c) 0.50 (d)0.25

IES-96. Ans. (b) Degree of reaction,

$$R = \frac{\text{Enthalpy rise in rotor}}{\text{Enthalpy rise in the stage}}$$

$$DR = 1 - \frac{V_{w2}}{2V_b} = 1 - \frac{1}{2 \times 2} = 0.75$$

IES-97. 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 **[IES-1998]**
(c) Progressively increase (d) Depend upon the number of stages

IES-97. Ans. (b) as pressure increases volume will decrease

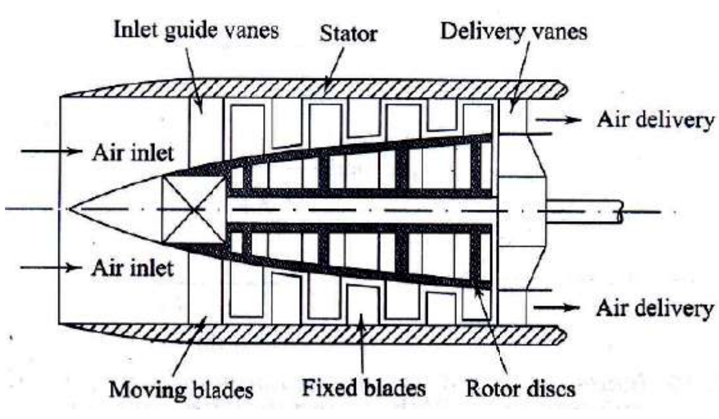
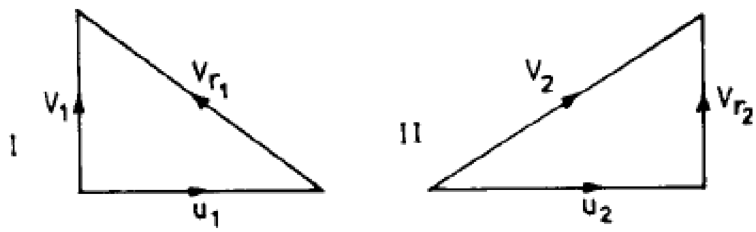


Fig. Axial flow compressor

IES-98. The inlet and exit velocity diagrams of a turbo-machine rotor are shown in the Figure I and Figure II respectively. [IES-1995]



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.

IES-98. Ans. (a) Velocity diagrams are for axial compressor ($u_1 = u_2$) with radial blades (V_1 and V_{r2}) are perpendicular to u_1 and u_2).

IES-99. In a multi-stage axial flow compressor with equal temperature rise in all stages, the pressure ratio in the subsequent stages [IES-2007]
(a) Remains constant (b) Increases gradually
(c) Decreases (d) Increases rapidly

IES-99. Ans. (a)

IES-110. Consider the following statements in respect of axial flow compressor:
1. An axial flow air compressor is often describe is a reversed reaction turbine. [IES-2007]
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-110. Ans. (c)

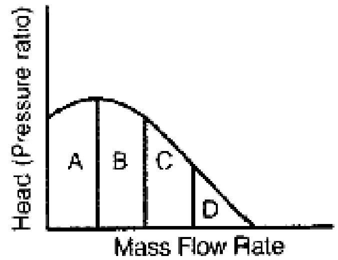
IES-111. Stalling phenomena in an axial flow compressor stage is caused due to which one of the following? [IES-2007]
(a) Higher mass flow rate than the designed value
(b) Lower mass flow rate than the designed value
(c) Higher mass flow rate or non-uniformity in the blade profile
(d) Lower mass flow rate or non-uniformity in the blade profile

IES-111. Ans. (d)

IES-112. Consider the following statements regarding the axial flow in an air compressor: [IES-2001]
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-112. Ans. (c)

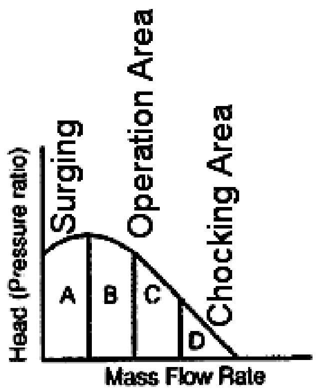
IES-113. In the graph as shown above, for an axial flow compressor, surging is likely to occur in which one of the following zones?



[IES-2009]

(a) A (b) B (c) C (d) D

IES-113. Ans. (a)



IES-114. High positive incidence in an axial compressor blade row leads to: **[IES-1994]**
(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-114. Ans. (a)

IES-115. Assertion (A): In axial flow compressors, momentum blading is more efficient than radial flow blading. **[IES-1997]**
Reason (R): In radial flow blading, the pressure head increases due to centrifugal head.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-115. Ans. (b)

IES-116. 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. **[IES-1995]**
Reason (R): The isentropic efficiency of axial flow compressor is much higher than that of a centrifugal compressor.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-116. Ans. (a) Both A and R are correct and R provides right explanation for A.

IES-117. In air-craft gas turbines, the axial flow compressor is preferred because
(a) Of high pressure rise
(b) It is stall free **[IES-1993]**
(c) Of low frontal area
(d) Of higher thrust

IES-117. Ans. (c) Axial flow compressor is preferred in aircraft gas turbines because of requirement of low frontal area.

IES-118. In axial flow compressor, exit flow angle deviation from the blade angle is a function of: **[IES-1993]**
(a) Blade camber
(b) Space-chord ratio
(c) Both blade camber and space-chord ratio
(d) Blade camber and incidence angle

IES-118. Ans. (c)

IES-119. Match List-I with List-II (Pertaining to blower performance) and select the correct answer using the codes given below the lists: **[IES-1997]**

List-I	**List-II**
A. Slip	**1.** Reduction of whirl velocity
B. Stall	**2.** Fixed mass flow rate regardless of pressure ratio
C. Choking	**3.** Flow separation
	4. Flow area reduction

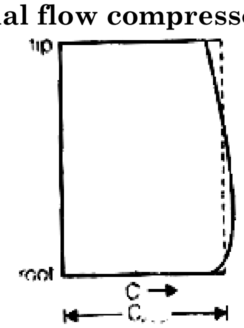
Codes:	**A**	**B**	**C**		**A**	**B**	**C**
(a)	4	3	2	(b)	4	1	3
(c)	1	3	2	(d)	2	3	4

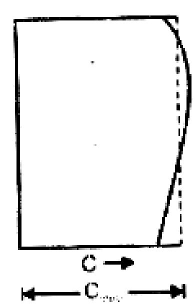
IES-119. Ans. (c)

IES-120. Under which one of the following sets of conditions will a supersonic compressor have the highest efficiency? **[IES-1995]**
(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.

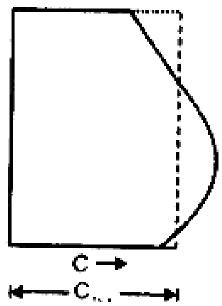
IES-120. Ans. (d)

IES-121. Which one of the following diagrams depicts correctly the radial distribution of axial velocity over the blades in the last stage of multistage axial flow compressors? **[IES-2009]**

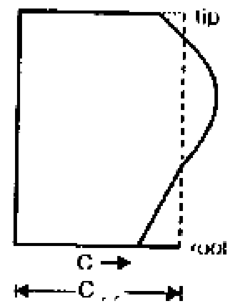
(a)


(b)


(c)



(d)



IES-121. Ans. (c)

Flash Chamber

IES-122. 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

IES-122. Ans. (d) Flash chamber has no effect on refrigerating effect.

IES-123. Match List-I with List-II and select the correct answer using the codes given below the lists: **[IES-1998]**

List-I	List-II
A. Bell Colemn refrigeration	**1.** Compressor
B. Vapour compression refrigeration	**2.** Generator
C. Absorption refrigeration	**3.** Flash chamber
D. Jet refrigeration	**4.** Expansion cylinder

Codes:	**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

IES-123. Ans. (d)

IES-124. Match List-I (Cycle) with List-II (Equipment) and select the correct answer using the code given below the lists: **[IES-2008]**

List-I	List-II
A. Air refrigeration	**1.** Absorber
B. Vapour compression refrigeration	**2.** Flash chamber
C. Vapour absorption refrigeration	**3.** Turbine
D. Steam jet refrigeration	**4.** Compressor

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

IES-124. Ans. (c)

Previous 20-Years IAS Questions

Types of Compressors

IAS-1. What is the cause of burn out of hermetically sealed refrigerant compressors? [IAS-2007]
(a) Phase to phase short because of worn insulation
(b) By prolonged overload operation
(c) By some mechanical failure
(d) All the above

IAS-1. Ans. (d)

IAS-2. Which of the following are the special features of a hermetically sealed compressor of a refrigerator? [IAS-1999]
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

IAS-2. Ans. (b)

IAS-3. Use of hermetically sealed compressor in a vapour compression refrigeration system results in [IAS-1998]
(a) Decrease in energy consumption (b) Increase in energy consumption
(c) Increase in COP (d) Increase in pressure ratio

IAS-3. Ans. (b)

IAS-4. When does L.P. cut-off occur in a refrigeration system? [IAS-2004]
(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

IAS-4. Ans. (a)

Volumetric Efficiency of reciprocating Compressors

IAS-5. The clearance volume of a reciprocating compressor directly affects
(a) Piston speed (b) Noise level **[IAS-1998]**
(c) Volumetric efficiency (d) Temperature of air after compression

IAS-5. Ans. (c) $\eta_v = 1 + c - c\left(\frac{P_2}{P_1}\right)^{1/n}$

IAS-6. 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.
4. Clearance volume.
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

IAS-6. Ans. (d) The reason for volumetric efficiency of reciprocating compressor being less that 100% are pressure drop across the valves, superheating in compressor, clearance volume and leakages.

Effect of Clearance on Work

IAS-7. Consider the following statements: [IAS-2000]
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

IAS-7. Ans. (a) In centrifugal compressor there also isentropic compression occurs so.

Performance Characteristics of Reciprocating Compressors

IAS-8. Performance of a reciprocating compressor is expressed by: [IAS-2003]

(a) $\dfrac{\text{Isothermal work}}{\text{Indicated work}}$ (b) $\dfrac{\text{Indicated work}}{\text{Isothermal work}}$

(c) $\dfrac{\text{Adiabatic work}}{\text{Indicated work}}$ (d) $\dfrac{\text{Indicated work}}{\text{Adiabatic work}}$

IAS-8. Ans. (a)

IAS-9. The isothermal efficiency of a reciprocating compressor is defined as actual work done during compression [IAS-1994]

(a) $\dfrac{\text{Actual work done during compression}}{\text{Isothermal work done during compression}}$

(b) $\dfrac{\text{Adiabatic work done during compression}}{\text{Isothermal work done during compression}}$

(c) $\dfrac{\text{Isothermal work done during compression}}{\text{Actual work done during compression}}$

(d) $\dfrac{\text{Isothermal work done during compression}}{\text{Actual work done during adiabatic compression}}$

IAS-9. Ans. (c)

Rotary Compressors

IAS-10. A rotary compressor is used when a refrigerating system has to handle a refrigerant with [IAS-1997]
(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

IAS-10. Ans. (d)

Axial flow compressor

IAS-11. Consider the following characteristics: [IAS-2002]

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

IAS-11. Ans. (b) In Axial flow pumps the fluid both enters and discharged axially.

Flash Chamber

IAS-12. Flash chamber is used in refrigeration for which one of the following?
(a)Decreasing the pressure during multistage compression **[IAS-2007]**
(b)Increasing the compressor pressure ratio
(c)Effective inter-cooling medium for purpose of increasing COP
(d)Maintaining the same pressure and temperature

IAS-12. Ans. (c)

5. Condensers & Evaporator

OBJECTIVE QUESTIONS (GATE, IES, IAS)

Previous 20-Years GATE Questions

Types of Condensers

GATE-1 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: [GATE-1992; IES-1995]

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

GATE-1 Ans. (c) Heat rejected in condenser = 120 kW: Compressor work = 30 kW;
Net refrigeration effect = 120 - 30 = 90 kW.
Therefore, COP = 90/30 = 3

Previous 20-Years IES Questions

Types of Condensers

IES-1. or small installations of refrigeration systems (up to 35 kW), which type of condenser is used? [IES-2006]

(a) Shell and tube type (b) Shell and coil type
(c) Double tube type (d) Air cooled type

IES-1. Ans. (c) 1 TR = 3.5 KW

Double Pipe or tube-in-tube type:
Double pipe condensers are normally used up to 10 TR capacity.
Shell-and-coil type:
These condensers are used in systems up to 50 TR capacity.
Shell-and-tube type:
This is the most common type of condenser used in systems from 2 TR upto thousands of TR capacity.

IES-2. 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: [GATE-1992; IES-1995]

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

IES-2. Ans. (c) Heat rejected in condenser = 120 kW: Compressor work = 30 kW;
Net refrigeration effect = 120 - 30 = 90 kW.
Therefore, COP = 90/30 = 3

IES-3. A pressure gauge on the discharge side of a refrigerant compressor reads too high. The reasons could be: [IES-1995]

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

IES-3. Ans. (b)

Heat Rejection Ratio

IES-4. In a vapour compressor refrigeration system, the compressor capacity is 420 kJ/min and refrigerating effect is 2100 kJ/minute and heat rejection factor is 1.2. What will, respectively be the heat rejected from the condenser and C OP? [IES-2004]

(a) 5040 kJ/minute and 5 (b) 2520 kJ/minute and 5
(c) 2520 kJ/minute and 4 (d) 5040 kJ/minute and 4

IES-4. Ans. (b) Heat rejection ratio (G)

= The loading on the condenser per unit of refrigeration

$$= \frac{Q_o + W}{Q_o} = 1 + \frac{W}{Q_o} = 1 + \frac{1}{COP}$$

or $G = 1 + \frac{1}{COP}$ or $1.2 = 1 + \frac{1}{COP}$ or $COP = 5$

Given $W = 420$ kJ/min

$\therefore Q_o = 2100$ kJ/min or $Q_o + W = 1.2.Q_o = 2520$ kJ/min

IES-5. 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? [IES-2005]

(a) 3 (b) 5 (c) 7 (d) 9

IES-5. Ans. (b) $\frac{Q_1}{Q_2} = 1.2$ or $\frac{Q_2}{Q_1 - Q_2} = \frac{1}{0.2} = 5 = COP$

IES-6. 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: [IES-2002]

(a) 15 (b) 20 (c) 25 (d) 75

IES-6. Ans. (c)

IES-7. In vapour compression refrigeration system, at entrance to which component the working fluid is superheated vapour? [IES-2009]

(a) Evaporator (b) Condenser
(c) Compressor (d) Expansion valve

IES-7. Ans. (b)

Evaporators

IES-8. The deposition of frost on evaporator tubes of an air conditioner will result in [IES-1992]

(a) Decrease in heat transfer (b) Increase in heat transfer
(c) No change in heat transfer (d) Increase in capacity of evaporator

IES-8. Ans. (a)

Previous 20-Years IAS Questions

Types of Condensers

IAS-1. **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.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-1. Ans. (a) But most important cause is high heat transfer coefficient.

Evaporators

IAS-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? [IAS-2004]**
(a) It increases continuously
(b) It decreases and then becomes constant
(c) It increases, reaches a peak and then decreases
(d) It remains constant

IAS-2. Ans. (a)

6. Expansion Devices

OBJECTIVE QUESTIONS (GATE, IES, IAS)

Previous 20-Years GATE Questions

Capillary Tube and Its Sizing

GATE-1 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

GATE-1 Ans. (a)

Previous 20-Years IES Questions

Types of Expansion Devices

IES-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-l	List-II
A. Float valve	**1.** Constant degree of superheat at evaporator exit pressure
B. Automatic expansion valve	**2.** Constant degree of superheat at evaporator inlet pressure
C. Internally equalized thermostatic expansion valve	**3.** Constant level of refrigerant in the evaporator
D. Externally equalized thermostatic expansion valve	**4.** Constant pressure in the evaporator

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

IES-1. Ans. (c)

Thermostatic-Expansion Valve

IES-2. The sensing bulb of the thermostatic expansion valve is located at the
(a) Exit of the evaporator (b) Inlet of the evaporator **[IES-2002]**
(c) Exit of the condenser (d) Inlet of the condenser

IES-2. Ans. (a)

IES-3. A valve which maintains a constant degree of superheat at the end of the evaporator coil, is called [IES-1993]
(a) Automatic expansion valve (b) High side float valve
(c) Thermostatic expansion valve (d) Low side float valve

IES-3. Ans. (c)

IES-4. Which one of the following is responsible for the operation of a thermostatic expansion valve? [IES-2005]
(a) Pressure changes in evaporator (b) Temperature changes in evaporator
(c) Degree of superheat in evaporator (d) Degree of subcooling in evaporator

IES-4. Ans. (c)

IES-5. A thermostatic expansion value in refrigeration system [IES-1992]
(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

IES-5. Ans. (a)

IES-6. What is hunting of thermostatic expansion valve? [IES-2008]
(a) A variation of evaporator load with degree of Super heat
(b) A variation in pressure of the evaporator with variation of load
(c) Alternate overfeeding and starving of refrigerant flow in the evaporator
(d) This is not used in connection with expansion valve

IES-6. Ans. (c)

Capillary Tube and Its Sizing

IES-7. Consider the following statements: [IES-2000; IAS-1999]
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

IES-7. Ans. (a)

IES-8. In a domestic refrigerator, a capillary tube controls the flow of refrigerant from the [IES-1994]
(a) Expansion valve to the evaporator (b) Evaporator to the thermostat
(c) Condenser to the expansion valve (d) Condenser to the evaporator

IES-8. Ans. (d) In domestic refrigerator, a capillary tube controls the flow of refrigerant from condenser to evaporator

Previous 20-Years IAS Questions

Types of Expansion Devices

IAS-1. An expansion valve is NOT used for reducing pressure in the [IAS-2000]
(a) Vapour compression refrigeration (b) Vapour absorption refrigeration cycle
(c) Steam-jet refrigeration cycle (d) Gas refrigeration cycle

IAS-1. Ans. (d) Steam-jet refrigeration cycle is similar to vapour compression refrigeration cycle where mechanical compressor is substituted by steam ejector or booster.

Automatic or Constant-Pressure Expansion Valve

IAS-2. 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

IAS-2. Ans. (b)

IAS-3. An automatic expansion value is required to maintain constant [IAS-1998]

(a) Pressure in the evaporator (b) Temperature in the freezer
(c) Pressure in the liquid line (d) Temperature in the condenser

IAS-3. Ans. (a)

Thermostatic-Expansion Valve

IAS-4. Which one of the following is the most important function of thermostatic expansion valve? [IAS-2003]

(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

IAS-4. Ans. (a)

IAS-5. Consider the following statements: [IAS-1999]
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

IAS-5. Ans. (c)

Capillary Tube and Its Sizing

IAS-6. Consider the following statements: [IAS-1999; IES-2000]
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

IAS-6. Ans. (a)

IAS-7. 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

IAS-7. Ans. (a)

IAS-8. Which of the features of expansion valves in the following lists are correctly matched? [IAS-2004]

Expansion Device		**Feature**
1. Capillary tube	**:**	**Choking**
2. Thermostatic expansion valve	**:**	**Constant temperature**
3. Automatic Expansion valve	**:**	**Constant degree of superheat**
4. Float valve	**:**	**Mass flow rate of refrigerant is proportional to**

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

IAS-8. Ans. (c)

IAS-9. 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

IAS-9. Ans. (d)

7. Gas Cycle Refrigeration

OBJECTIVE QUESTIONS (GATE, IES, IAS)

Previous 20-Years IES Questions

Limitations of Carnot Cycle with Gas as a Refrigerant

IES-1. Where is an air refrigeration cycle generally employed? [IES-1998; 2006]
(a) Domestic refrigerators (b) Commercial refrigerators
(c) Air-conditioning (d) Gas liquefaction

IES-1. Ans. (d)

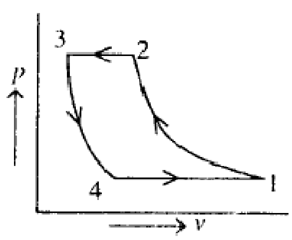
IES-2. In aircraft, air refrigeration cycle is used because of [IES-1995]
(a) Low unit weight per tonne of refrigeration
(b) High heat transfer rate
(c) Lower temperature at high-altitudes
(d) Higher coefficient of performance

IES-2. Ans. (a)

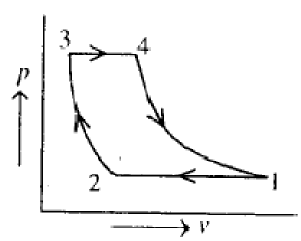
Reversed Brayton or Joule or Bell Coleman Cycle

IES-3. Which one of the following is the p-v diagram for air refrigeration cycle?

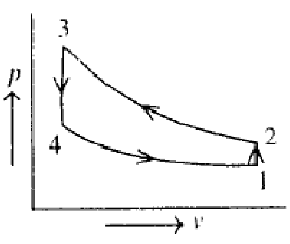
(a)



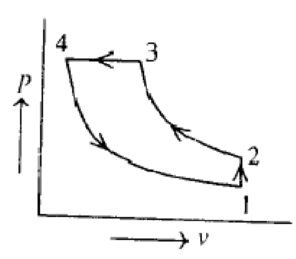
(b)



(c)



(d)



IES-3. Ans. (a)

IES-4. 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]

List-I	List-II
A. Compression	**1.** Isobaric

B. Heat rejection					**2.** Isothermal				
C. Expansion					**3.** Isentropic				
D. Heat absorption					**4.** Isenthalpic				
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

IES-4. Ans. (b)

IES-5. When the Brayton cycle working in the pressure limits of p1 and p2 is reversed and operated as a refrigerator, what is the ideal value of COP for such a cycle? [IES-2007]

(a) $\left(\dfrac{p_2}{p_1}\right)^{\gamma-1}-1$
(b) $\dfrac{1}{\left(\dfrac{p_2}{p_1}\right)^{\gamma-1}-1}$
(c) $\dfrac{1}{\left(\dfrac{p_2}{p_1}\right)^{\left\{(\gamma-1)/\gamma\right\}}-1}$
(d) None of the above

IES-5. Ans. (c) $\eta_{H.E} = 1-\dfrac{1}{r_p^{(\gamma-1)/\gamma}}$; $\therefore$ (COP)H.P= $\dfrac{1}{\eta_{H.E}} = \dfrac{r_p^{\frac{\gamma-1}{\gamma}}}{r_p^{\frac{\gamma-1}{\gamma}}-1}$

(COP)R = (COP)H.P – 1 = $\dfrac{1}{r_p^{\frac{\gamma-1}{\gamma}}-1} = \dfrac{1}{\left(\dfrac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}-1}$

Application to Aircraft Refrigeration

IES-6. While designing the refrigeration system of an aircraft prime consideration is that the [IES-1993]

(a) System has high C.O.P.
(b) H.P./ton is low
(c) Weight of refrigerant circulated in the system is low
(d) Weight of the refrigeration equipment is low ·

IES-6. Ans. (d)

Simple Evaporative

IES-7. 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

IES-7. Ans. (a)

Boot-strap Evaporative

IES-8. 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

IES-8. Ans. (d) Actually for this use Reduced Ambient system of refrigeration.

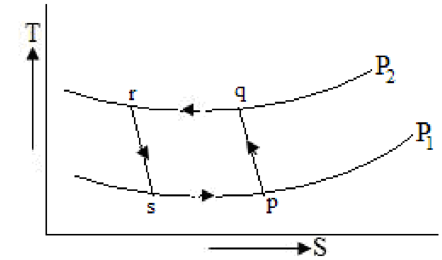
Previous 20-Years IAS Questions

Reversed Brayton or Joule or Bell Coleman Cycle

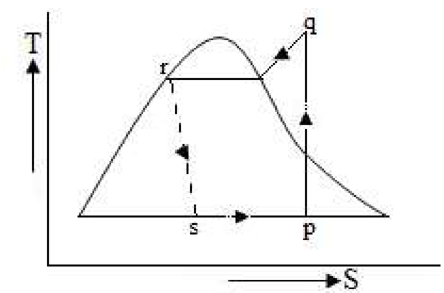
IAS-1. Match List I with List II and select the correct answer using the codes given below lists: [IAS-1994]

List-I

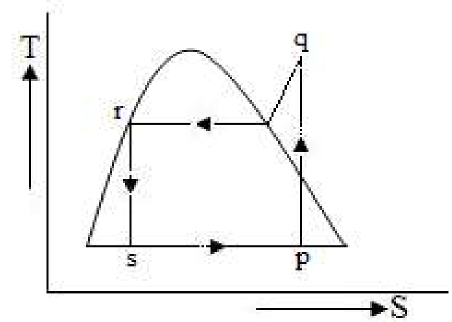
A.



B.



C.



List-II

1. Vapour compression cycle using expansion valve

2. Bell-Coleman cycle (gas compression cycle)

3. Vapour compression cycle using expansion engine

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

IAS-1. Ans. (d)

8. Vapour Absorption System

OBJECTIVE QUESTIONS (GATE, IES, IAS)

Previous 20-Years GATE Questions

Simple Vapour Absorption System

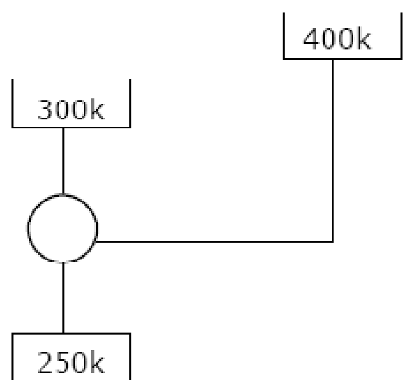
GATE-1. **List-I** **List II** **[GATE-1997]**

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

GATE-1. Ans. (A) –2, (B) –4, (C) –6, (D) –1

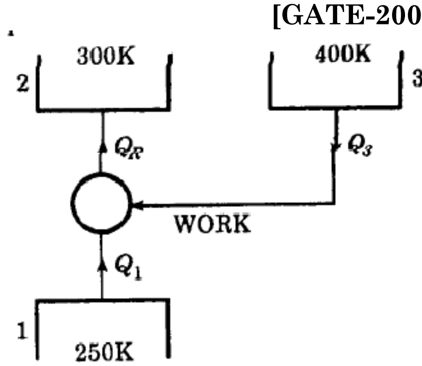
ATE-2. **A vapour absorption refrigeration system is a heat pump with three thermal reservoirs as shown in the figure. A refrigeration effect of 100 W is required at 250 K when the heat source available is at 400 K. Heat rejection occurs at 300 K. The minimum value of heat required (in W) is:**

(a) 167 (b) 100
(c) 80 (d) 20



[GATE-2005]

ATE-2. Ans. (c) From question, since refrigeration effect of 100 W is required



$$\text{So, } \frac{100}{\text{Work obtained}} = \frac{250}{300-250}$$

$$\Rightarrow \quad \text{Work obtained} = \frac{100 \times 50}{250} = 20\,\text{W}$$

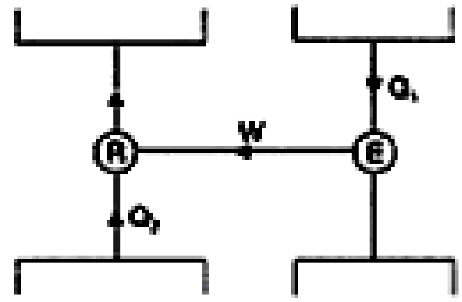
Now for this amount of work, heat is absorbed from reservoir 3 and rejected to sink 2.

$\therefore \qquad \eta = \dfrac{W}{Q_3} = 1 - \dfrac{300}{400} = \dfrac{1}{4} \qquad \Rightarrow Q_3 = 4\,W = 4 \times 20\,W = 80\,W$

GATE-3. A heat engine having an efficiency of 70% is used to drive a refrigerator having a co-efficient 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]

(a) 0.14 kJ (b) 0.71 kJ (c) 3.5 kJ (d) 7.1 kJ

ATE-3. Ans. (c)



Given, $\eta_{\text{reservoir}} = 0.7, \quad (\text{COP})_R = 5$

$$\eta_{\text{reservoir}} = \frac{W}{Q_1} \qquad ...(i)$$

Now, $(\text{COP})_R = \dfrac{Q_2}{W}$

$\Rightarrow \qquad 5 = \dfrac{Q_2}{W}$

$\therefore \qquad W = \dfrac{Q_2}{5} \qquad ...(ii)$

Again, $0.7 = \dfrac{Q_2}{5} \times \dfrac{1}{Q_1} \quad \Rightarrow \dfrac{Q_2}{Q_1} = 3.5$

Energy absorbed from low temperature reservoir by the refrigerator for each kJ of energy absorbed from high temperature source by the engine –3.5 kJ.

Previous 20-Years IES Questions

Simple Vapour Absorption System

IES-1. In a vapour absorption refrigerator, heat is rejected in: [IES-2006]

(a) Condenser only (b) Generator only
(c) Absorber only (d) Condenser and absorber

IES-1. Ans. (d)

IES-2. Assertion (A): In remote places, the use of absorption refrigeration system plant is more advantageous when compared to vapour compression plant.[IES-1993]
Reason (R): The absorption system can use relatively low temperature heat as energy source.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-2. 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.

IES-3. 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 **[IES-1999]**
(c) Carbon dioxide-water (d) Ammonia-water

IES-3. Ans. (d)

IES-4. Solar energy can be directly used in [IES-1999]
(a) Vapour compression refrigeration system
(b) Vapour absorption refrigeration system
(c) Air refrigeration system
(d) Jet refrigeration system

IES-4. Ans. (b)

IES-5. Vapour absorption refrigeration system works using the [IES-1997]
(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

IES-5. Ans. (c) Vapour absorption refrigeration system works using the affinity of a substance for another substance.

IES-6. Which one of the following statements regarding ammonia absorption system is correct? [IES-1997]
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

IES-6. Ans. (c)

IES-7. The refrigerant used for absorption refrigerators working heat from solar collectors is a mixture of water and [IES-1996]
(a) Carbon dioxide (b) Sulphur dioxide
(c) Lithium bromide (d) Freon 12

IES-7. Ans. (c) The refrigerant used for absorption refrigerators working on heat from solar collectors is a mixture of water and lithium bromide.

IES-8. Waste heat can be effectively used in which one of the following refrigeration systems? [IES-1995]
(a) Vapour compression cycle (b) Vapour absorption cycle
(c) Air refrigeration cycle (d) Vortex refrigeration system

IES-8. Ans. (b) Waste heat can be utilized in vapour absorption cycle.

IES-9. 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]

List-I	**List-II**
A. Generator	**1.** Dehydration
B. Analyzer	**2.** Removal of vapour from strong aqua-ammonia solution
C. Rectifier	**3.** Producing dry ammonia vapour by removing traces of water particles completely
D. Receiver	**4.** Storage of high pressure liquid ammonia
	5. Formation of liquid ammonia from high pressure vapours.

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

(c) 1 3 2 5 (d) 2 1 3 4

IES-9. Ans. (d)

Maximum Coefficient of Performance of a Heat Operated Refrigerating Machine

IES-10. In vapour absorption refrigeration system heating in generator is done at 177°C, refrigeration in evaporator at –3°C and cooling in condenser at 27°C. Then what will be the maximum COP of the system? [IES-2009]

(a) 1.5 (b) 2.3 (c) 3.0 (d) 4.0

IES-10. Ans. (c) COP of Refrigerator

$$= \eta_{H.E} \times \text{COP}_R = \left(1 - \frac{T_C}{T_G}\right)\left(\frac{T_E}{T_C - T_E}\right) = \left(1 - \frac{300}{450}\right)\left(\frac{270}{300 - 270}\right) = 3$$

IES-11. 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-2001; 2002]**

IES-11. Ans. (d) Page no 321 Q no 104

IES-12. Theoretical maximum COP of a vapour absorption system (where, TG = generator temp, TE = evaporator temp, To = environmental temp) is: [IES-1998; 2003]

(a) $\frac{T_E}{T_G}\left(\frac{T_G - T_O}{T_O - T_E}\right)$ (b) $\frac{T_E}{T_G}\left(\frac{T_O - T_E}{T_G - T_O}\right)$ (c) $\frac{T_G}{T_E}\left(\frac{T_G - T_O}{T_O - T_E}\right)$ (d) $\frac{T_G}{T_E}\left(\frac{T_O - T_E}{T_G - T_O}\right)$

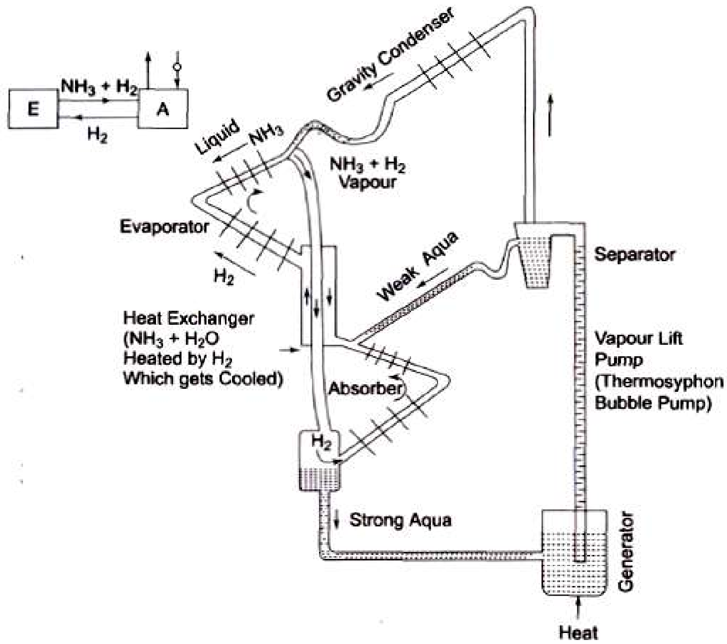
IES-12. Ans. (a)

Electrolux Refrigerator

IES-13. In an Electrolux refrigerator: [IES-2005]

(a) Ammonia is absorbed in water
(b) Ammonia is a absorbed in hydrogen
(c) Hydrogen is evaporated in ammonia
(d) Ammonia evaporated in hydrogen

IES-13. Ans. (d)



IES-14. **Hydrogen is essential in an Electrolux refrigeration system, because**
(a) It acts as a catalyst in the evaporator **[IES-1997]**
(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

IES-14. Ans. (d) Hydrogen gas in Electrolux refrigerator helps in maintaining a low partial pressure for the evaporating ammonia.

Previous 20-Years IAS Questions

Simple Vapour Absorption System

IAS-1. **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

IAS-1. Ans. (a)

IAS-2. **In the absorption refrigeration cycle, the compressor of the vapour compression refrigeration cycle is replaced by:** **[IAS-1994; 2000]**
(a) Liquid pump (b) Generator
(c) Absorber and generator (d) Absorber, liquid pump and generator

IAS-2. Ans. (d) The compressor of vapour compression refrigeration cycle is replaced by absorber, liquid pump and generator in the absorption refrigeration cycle.

Maximum Coefficient of Performance of a Heat Operated Refrigerating Machine

IAS-3. **A reversible heat engine runs between high temperature T1 and low temperature T2. The work output of this heat engine is used to run reversible refrigeration cycle absorbing heat at temperature T3 and rejecting at temperature T2. What is the COP of the combined system?** **[IAS-2004]**

(a) $\left(\frac{T_1 - T_2}{T_1}\right)\left(\frac{T_3}{T_2 - T_3}\right)$ (b) $\left(\frac{T_2}{T_1 - T_2}\right)\left(\frac{T_2 - T_3}{T_3}\right)$

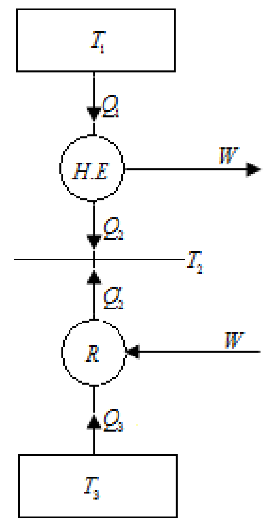
(c) $\left(\frac{T_1}{T_1 - T_2}\right)\left(\frac{T_3}{T_2 - T_3}\right)$ (d) $\left(\frac{T_3}{T_1 - T_3}\right)\left(\frac{T_1}{T_2 - T_1}\right)$

IAS-3. Ans. (a) $\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_1 - Q_2}{T_1 - T_2} = \frac{W}{T_1 - T_2}$ or $W = \frac{Q_1}{T_1} \times (T_1 - T_2)$

$\frac{Q_3}{T_3} = \frac{Q_2^1}{T_2} = \frac{Q_2^1 - Q_3}{T_2 - T_3} = \frac{W}{T_2 - T_3}$ or $W = \frac{Q_3}{T_3} \times (T_2 - T_3)$

or $\frac{Q_1}{T_1}(T_1 - T_2) = \frac{Q_3}{T_3}(T_1 - T_3)$

or $COP = \frac{Q_3}{Q_1} = \left(\frac{T_3}{T_2 - T_3}\right) \times \left(\frac{T_1 - T_2}{T_1}\right)$



IAS-4. **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

IAS-4. Ans. (d)

9. Psychrometry

OBJECTIVE QUESTIONS (GATE, IES, IAS)

Previous 20-Years GATE Questions

Specific humidity or Humidity ratio

GATE-1. 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 and enthalpy (kJ/kg of dry air) of this moist air respectively, are (a) 0.01051, 52.64 (b) 0.01291, 63.15 **[GATE-2004]**
(c) 0.01481, 78.60 (d) 0.01532, 81.40

GATE-1Ans. (B) Given, P = 1.013 bar
PV = 0.02062 (at dew point)
We know that

$$\text{Specific humidity} = \frac{0.622P_v}{P-P_v}$$

$$= \frac{0.622\times 0.02062}{1.013-0.02062}$$

= 0.01291 kg / kg of dry air

enthalpy (h) = 1.022 td+ W (h_{fgdp} + 2.3 t_{dp})
= 1.022 ×30 + 0.01291 (2500 + 2.3 × 18)
= 1.022 × 30 + 32.809
= 63.47 kJ / kg of dry air

Relative humidity

GATE-2. A moist air sample has dry bulb temperature of 30°C and specific humidity of 11.5 g water vapour per kg dry air. Assume molecular weight of air as 28.93. If the saturation vapour pressure of water at 30°C is 4.24 kPa and the total pressure is 90 kPa, then the relative humidity (in %) of air sample is
(a) 50.5 (b) 38.5 (c) 56.5 (d) 68.5 **[GATE-2010]**

GATE-2Ans. (b)

Given,

$$w = 11.5 \times 10^{-3}\,\text{kJ / kg of dry air}$$

$$w = 0.622\frac{P_v}{P - P_v};\ \text{after substituting}$$

$$P_v = 1.62\,\text{KPa}$$

$$\therefore \text{Relative humidity(in\%)} = \frac{P_v}{P_{vs}} = \frac{1.62}{4.24} \times 100\% = 38\%$$

GATE-3. 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 [GATE-2005]

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

GATE-3Ans. (b) Here, $\phi = \frac{P_v}{P_s}$

$$\Rightarrow \quad P_v = \phi.P_s$$

$$(P_s)_{33^0 c} = 0.05628\,\text{bar}$$

$$\omega = 0.622P_v$$

GATE-4. For air at a given temperature, as the relative humidity is increased isothermally, [GATE-2001]

(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

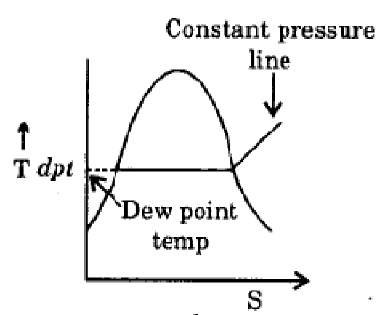
GATE-4Ans. (a, c)

Dew point temperature

GATE-5. Dew point temperature is the temperature at which condensation begins when the air is cooled at constant [GATE-2006]

(a) volume (b) entropy (c) pressure (d) enthalpy

GATE-5Ans. (c)



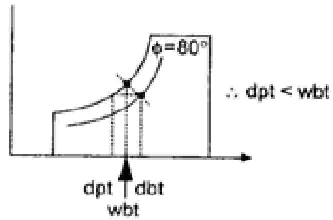
Air is cooled at constant pressure to make unsaturated air to saturated one.

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

GATE-6. For air with a relative humidity of 80% [GATE-2003]

(a) the dry bulb temperature is less than the wet bulb temperature
(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

GATE-6Ans. (b)



Psychrometric Chart

GATE-7. The statements concern Psychrometric chart. [GATE-2006]

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

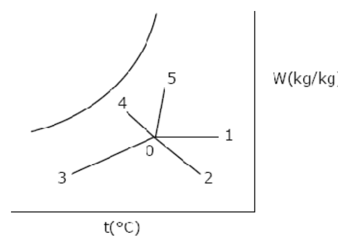
4. Constant enthalpy lines are coincident with constant wet bulb temperature lines

Which of the statements are correct?

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

GATE-7Ans. (a)

GATE-8. Various Psychrometric processes are shown in the figure below.



Process in Figure	**Name of the process**
P. 0-1	**1.Chemical dehumidification**
Q. 0-2	**2. Sensible heating**
R. 0-3	**3.Cooling and dehumidification**
S. 0-4	**4.Humidification with steam injection**
T. 0-5	**5.Humidification with water injection**

The matching pairs are **[GATE-2005]**

(a) P-1, Q-2, R-3, S-4, T-5 (b) P-2, Q-1, R-3, S-5, T-4

(c) P-2, Q-1, R-3, S-4, T-5 (d) P-3, Q-4, R-5, S-1, T-2

GATE-8Ans. (b)

GATE-9. When atmospheric air is heated at constant pressure, then which one is not correct. [GATE-2000]

(a) humidity ratio does not change

(b) relative humidity increases

(c) dew point temperature does not change

(d) wet bulb temperature increases

GATE-9Ans. (b)

GATE-10. During chemical dehumidification process of air [GATE-2004]

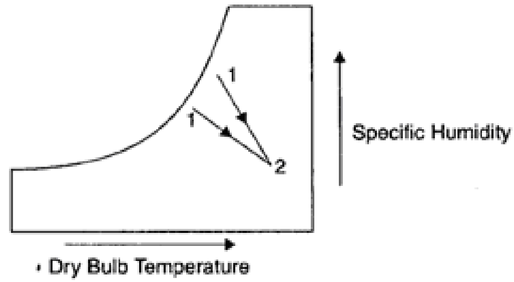
(a) dry bulb temperature and specific humidity decrease

(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

GATE-10Ans. (b)



GATE-11. 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? [GATE-2005]

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

GATE-11Ans. (b) Here, t_{DBT} = 40o, t_{WBT} = 20o
Water sprayed at temperature = 42o
Since, $t_{\text{water spray}} > t_{DBT}$ so heating and humidification.

Cooling and dehumidification

GATE-12. For the following "Matching" exercise, choose the correct one from among the alternatives [GATE-2000]
A, B, C and D

Group 1	**Group 2**
1. Marine Diesel Engine	**(A) Two stroke engine**
2. Air conditioning	**(B) Four stroke engine**
3. Steam Power Plant	**(C) Rotary engine**
4. Gas Turbine Power Plant	**(D) Cooling and dehumidification**
	(E) Cooling tower
	(F) Brayton cycle
	(G) Rankine cycle
	(H) D - slide valve

(a)	(b)	(c)	(d)
1-B	1-C	1-C	1-A
2-E	2-F	2-F	2-D
3-F	3-E	3-G	3-G
4-H	4-G	4-E	4-F

GATE-12Ans. (d)

Air Washer

GATE-13. 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
(A) 10^0C (B) 20^0C (C) 25^0C (D) 30^0C **[GATE-2008]**

GATE-13Ans. (C)

Air Conditioning

GATE-14. Moist air at a pressure of 100 kPa is compressed to 500 kPa and then cooled to 35^0C 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 [GATE-2008]

(A) 0.57 (B) 1.13 (C) 2.26 (D) 4.5

GATE-14Ans. (B) Volume change is one fifth and water vapour just compressed to one fifth volume so unsaturated vapour pressure= $\frac{5.628}{5} = 1.1256 \simeq 1.13 kPa$

Psychrometric Chart

GATE-15.The statements concern Psychrometric chart. [GATE-2006]

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

GATE-15Ans. (a)

Previous 20-Yrs IES Questions

Psychrometric Properties

IES-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

IES-1Ans. (c) A psychrometer measures wet bulb temperature and dry bulb temperature. It directly not measure dew point temperature.

IES-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

IES-2. Ans. (a) Specific heat of moist air = specific heat of dry air + humidity ratio x specific head of water vapour = 1.00 + 0.011 x 1.88 = 1.00 + 0.0207 = 1.0207 kJ/kgK.

Specific humidity or Humidity ratio

IES-3. 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

(a) $\frac{p_v}{p_a + p_v}$ (b) $\frac{p_v}{p_a}$ (c) $\frac{0.622 p_v}{p_a}$ (d) $\frac{0.622 p_v}{p_a + p_v}$ **[IES-;2001]**

IES-3Ans. (c) *We know* $p_a = p_b - p_v$

IES-4. The humidity ratio of atmospheric air at 28°C dbt and 760 mm of Hg is 0.016 kgv/kg-da. What is the partial pressure of water vapour? [IES-2009]
(a) 2.242kN/m² (b) 2.535kN/m² (c) 3.535kN/m² (d) 4.242kN/m²

IES-4Ans. (b)

$$\text{Humidity ratio} = 0.622\left(\frac{P_V}{P - P_V}\right)$$

$$\Rightarrow \quad 0.622\left(\frac{P_V}{100 - P_V}\right) = 0.016$$

$$\Rightarrow \quad P_V = 2.5\ \text{kN}/\text{m}^2$$

Relative humidity

IES-5. In a sample of moist air at standard atmospheric pressure of 101.325 kPa and 26°C the partial pressure of water vapour is 1.344 kPa. If the saturation pressure of water vapour is 3.36 kPa at 26° **C, then what are the humidity ratio and relative humidity of moist air sample? [IES-2009]**
(a) 0.00836 and 1.32% (b) 0.00836 and 40%
(c) 0.01344 and 1.32% (d) 0.01344 and 40%

IES-5Ans. (b)
Humidity ratio of Air

$$= 0.622\left(\frac{P_V}{P - P_V}\right)$$

$$= 0.622\left(\frac{1.344}{101.325 - 1.344}\right)$$

$$= 8.36 \times 10^{-3} = 0.00836\ \text{kgv}/\text{kg} - \text{da}$$

Relative humidity of Moist Air Sample

$$= \frac{P_V}{P_{V_s}} = \frac{1.344}{3.36} = 0.4 = 40\%$$

IES-6. 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

IES-6Ans. (a)

IES-7. 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 %

IES-7Ans. (d)

$$\text{Relative humidity(RH)}_1 = \frac{p_{v1}}{p_s} = 0.5 \quad or\ p_{v1} = 0.5 \times p_s$$

Where subscript 'v' refers to vapour state.

Where subscript 's' refers to saturation state.

$$p_{v2} = p_{v1} \times \left(\frac{V_2}{V_1}\right) = \left(0.5 p_s\right) \times \left(\frac{2V_1}{V_1}\right) = p_s$$

$$\therefore \text{Relative humidity(RH)}_2 = \frac{p_{v2}}{p_s} = \frac{p_s}{p_s} = 100\%$$

IES-8. The wet bulb depression is zero, when relative humidity is equal to
(a) 100% (b) 60% (c) 40% (d) Zero: **[IES-2006]**

IES-8Ans. (a)

IES-9. 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.

IES-9Ans. (d)

Dew point temperature

IES-10. What is the saturation temperature at the partial pressure of water vapour in the air-water vapour mixture called? **[IES-2009]**
(a) Dry bulb temperature (b) Web bulb temperature
(c) Dew point temperature (d) Saturation temperature

IES-10Ans. (c)

IES-11. In a cooling tower, the minimum temperature to which water can be cooled is equal to the **[IES-1995; 2001]**
(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

IES-11Ans. (c)

IES-12. In a chilled-water spray pond, the temperature of water is lower than dew point temperature of entering air. The air passing through the spray undergoes **[IES-1999]**
(a) cooling and humidification (b) cooling and dehumidification
(c) sensible cooling (d) dehumidification

IES-12Ans. (b) In this case condensation of moisture takes place which results in fall in specific humidity ratio. Cooling and dehumidification take place.

IES-13. When a stream of moist air is passed over a cold and dry cooling coil such that no condensation takes place, then the air stream will get cooled along the line of **[IES-1996]**
(a) constant web bulb temperature (b) constant dew point temperature
(c) constant relative humidity (d) constant enthalpy.

IES-13Ans. (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

Degree of saturation

IES-14. 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 ' ϕ ' and degree of saturation ' μ' is given by

(a) $\mu = \phi\left[\frac{p_b - p_s}{p_b - p_v}\right]$ (b) $\mu = \phi\left[\frac{p_b - p_v}{p_b - p_s}\right]$

(c) $\mu = \phi\frac{p_v}{p_b}$ (d) $\mu = \phi\frac{p_v}{p_s}$ **[IES-2001]**

IES-14Ans. (a)

IES-15. Air at state 1 (dpt 10°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

IES-15Ans. (c)

kg of moisture actually contained in mixture $= \frac{0.004 + 3\times 0.0051}{4} = 0.0048$

kg of moisture in saturated air of mixture $= 0.01$ kg/kg of air

So, Degree of saturation $= \frac{0.0048}{0.01}\times 100\% = 48\%$

IES-16. Match List I with List II and select the correct answer using the code given below the Lists: [IES-2005]

List I	List II
A Degree of saturation	**1. Measure of latent enthalpy of moist air**
B. Dry bulb temperature	**2. Measure of total enthalpy of moist air**
C. Wet bulb temperature	**3. Measure of the capacity of air to absorb moisture**
D. Dew point temperature	**4. Measure of sensible enthalpy of moist air**

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

IES-16Ans. (b)

IES-17. Consider the following statements: [IES-2004]

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

IES-17Ans. (d)

Wet Bulb Temperature (WBT)

IES-18. In a cooling tower the sum of range and approach is equal to twice the wet bulb depression. Then [IES-2003]
(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

IES-18Ans. (a)

T_i = inlet temperature of water in cooling tower

T_o = 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 $T_{db} = \dfrac{T_i + T_{wb}}{2}$

IES-19. 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 [IES-2002]
(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

IES-19Ans. (c)

IES-20. 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 4 (d) 2 and 3

IES-20Ans. (a) In case the relative humidity of air is 100% (saturated air) then
Dry bulb temperature
wet bulb temperature
dew point temperature
Saturation temperature ***will be equal***

IES-21. When the wet and dry bulb temperatures are identical, which of the following statements is/are true? [IES-2001; 2003]
1. Air is fully saturated
2. Dew point temperature is reached

3. Humidity ratio is unity
4. A 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

IES-21Ans. (b)

IES-22. When dry-bulb and wet-bulb temperatures are identical, it means that the **[IES-2000]**
(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

IES-22Ans. (a)

IES-23. At 100% relative humidity, the wet bulb temperature is **[IES-1995]**

(a) more than dew point temperature (b) same as dew point temperature
(c) less than dew point temperature (d) equal to ambient temperature.

IES-23Ans. (b)

IES-24. In a saturated air-water vapour mixture, the **[IES-1993]**
(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

IES-24Ans. (c) In a saturated air-water vapour mixture, the dry bulb, wet bulb and dew point temperatures are the same.

Adiabatic saturation of air and adiabatic saturation temperature

IES-25. During adiabatic saturation process of air, wet bulb temperature **[IES-1999]**
(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

IES-25Ans. (c)

IES-26. During the adiabatic cooling of moist air **[IES-1996]**
(a) DBT remains constant (b) specific humidity remains constant.
(c) relative humidity remains constant (d) WBT remains constant.

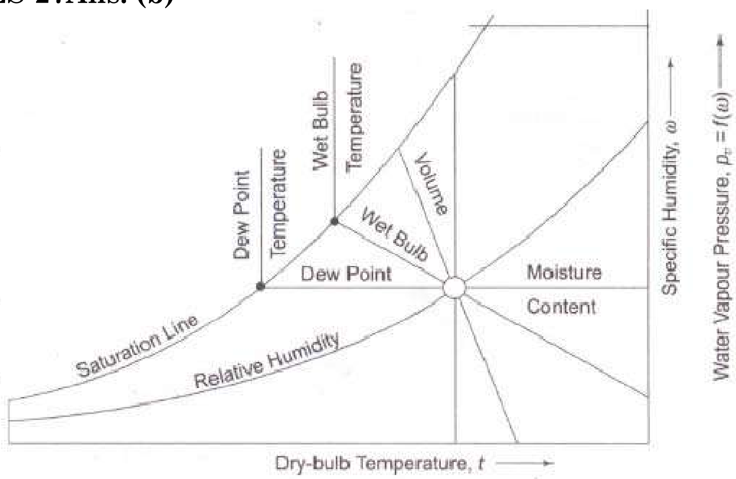
IES-26Ans. (d) During the adiabatic cooling of moist air, wet bulb temperature remains constant

Psychrometric Chart

IES-27. Consider the following statements: **[IES-2008]**
In a Psychrometric chart
1. vertical lines indicate wet bulb temperature.
2. horizontal lines indicate specific humidity.
3. sensible heating or cooling is represented by an inclined line.
Which of the statements given above is/are correct?

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

IES-27Ans. (b)

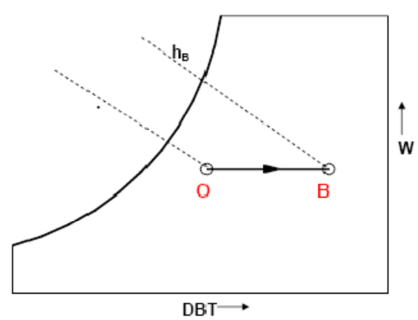


IES-28. On a Psychrometric chart, what does a vertical downward line represent? **[IES-2008]**
(a) Adiabatic saturation (b) Sensible cooling
(c) Dehumidification (d) Humidification

IES-28Ans. (c)

IES-29. Which of the following properties decrease(s) with sensible heating of air-water vapour mixture? **[IES-2008]**
1. Relative humidity
2. Humidity ratio
3. Specific enthalpy of air-vapour mixture
4. Wet bulb temperature
Select the correct answer using the code given below:
(a) 1 only (b) 1 and 3 (c) 2 and 3 (d) 2 and 4

IES-29Ans. (a)



Sensible heating process on psychrometric chart

IES-30. 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 Psychrometric chart, however, only two thermodynamic properties are needed since, Psychrometric chart **[IES-1993]**
(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

IES-30Ans. (d) The Psychrometric chart is drawn for a fixed pressure (standard atmospheric pressure) and thus only two thermodynamic properties are needed to fix thermodynamic state.

IES-31. To fix the state point in respect of air-vapour mixtures, three intrinsic properties are needed. Yet, the Psychrometric chart requires only two because [IES-1998]

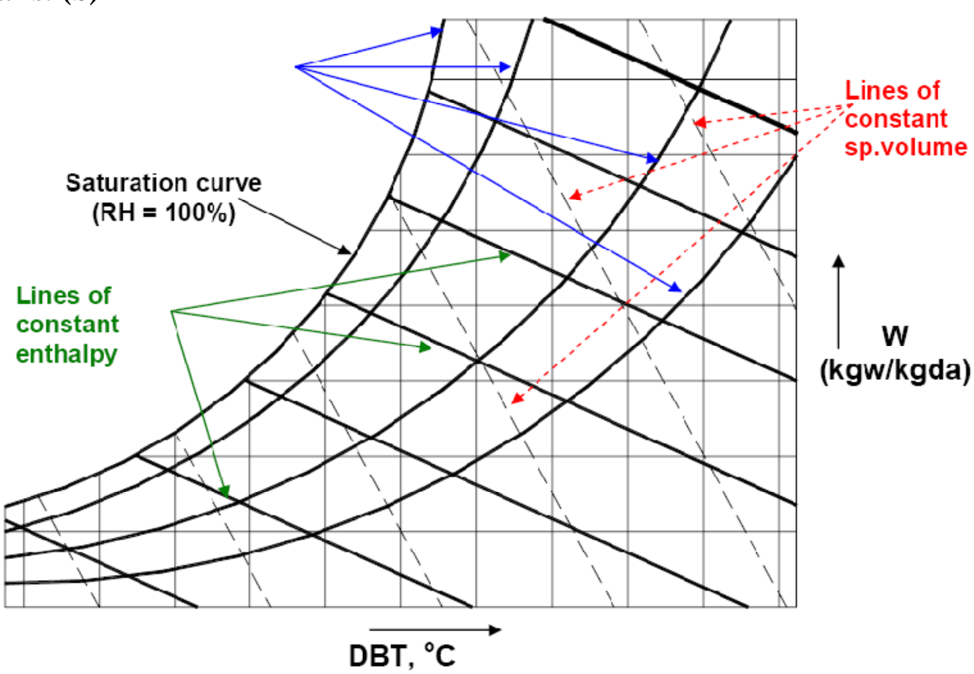
(a) water vapour is in the superheated state
(b) the chart is for a given pressure
(c) the chart is an approximation to true values
(d) the mixtures can be treated as a perfect gas

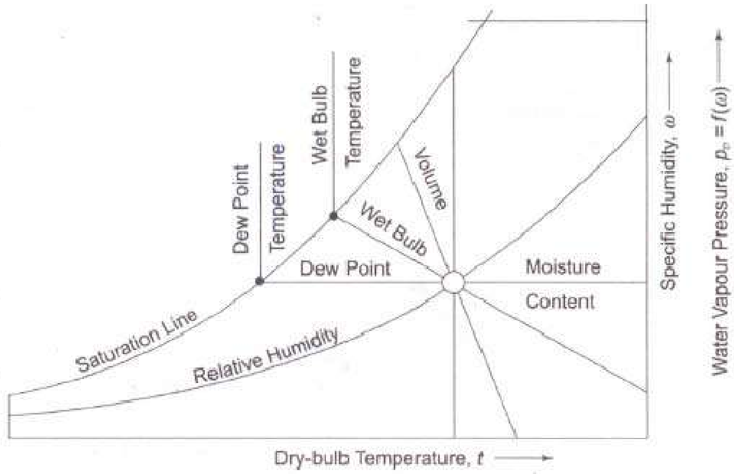
IES-31Ans. (b) Psychrometric chart is plotted for standard atmospheric pressure and as such only 2 coordinates are used to fix the state point. For pressures other than standard atmospheric, some correction is required.

IES-32. Which one of the following is correct? [IES-2008]
On Psychrometric chart, the constant wet bulb temperature lines coincide with.

(a) constant relative humidity lines
(b) constant enthalpy lines
(c) constant dew point temperature lines
(d) constant volume lines

IES-32ans. (b)





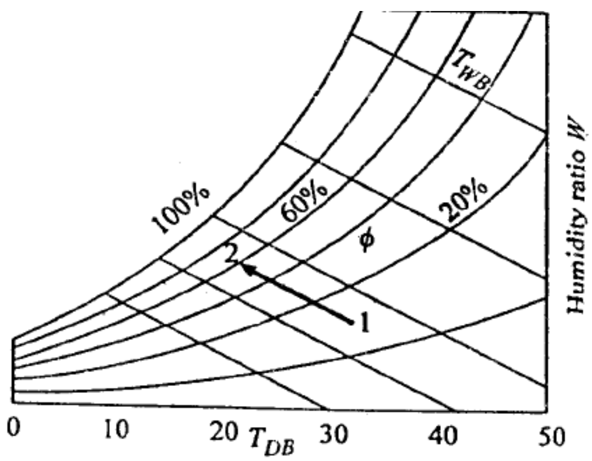
IES-33. Which one of the following is correct for the process 1-2 shown above?

(a) The partial pressure of water vapour in air remains constant

(b) Specific humidity of air remains constant

(c) Enthalpy of air remains constant

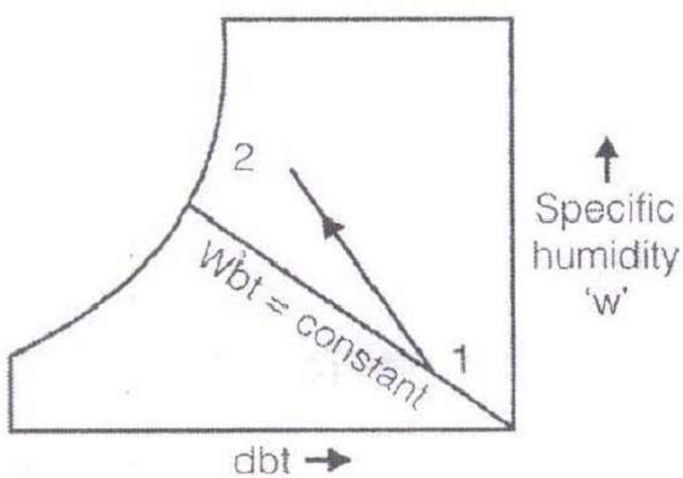
(d) Dry bulb temperature of air remains constant



[IES-2006]

IES-33Ans. (c)

IES-34.



Which one of the following statements is correct for a cooling and humidification process 1-2 as shown on the psychrometric chart above?

(a) Wbt decreases in the process **[IES-2009]**

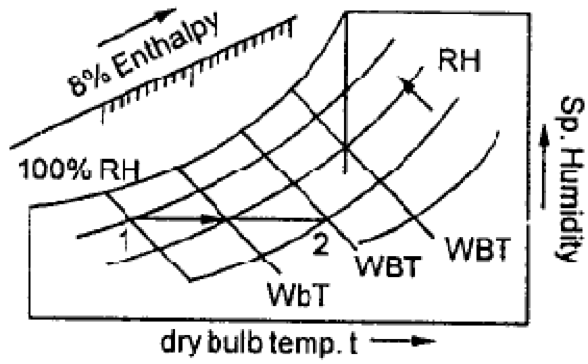
(b) The total enthalpy increases in the process

(c) The total enthalpy remains constant in the process
(d) It is an adiabatic saturation process

IES-34Ans. (b) We know that during cooling and humidification process, the enthalpy of air may increase, decrease or remain constant depending upon the temperature of the wet surface. Here the line diverges from wet bulb temperature line due to total enthalpy increases in the process.

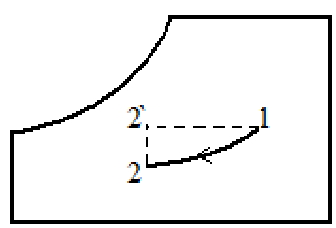
IES-35. Which of the following properties increasers) during sensible heating of air-water vapour-mixture? [IES-2003]
1. Relative humidity **2. Humidity ratio**
3. Wet bulb temperature **4. Specific enthalpy of air-vapour mixture**
Select the correct answer from the codes given below:
(a) 1 and 2 (b) 3 only (c) 2 and 3 (d) 3 and 4

IES-35Ans. (d)



IES-36. 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

IES-36Ans. (a)1-2 = 1-2` + 2`-2
cooling + de-humidification



[IES-2006]

IES-37. Consider the following statements: [IES-1995]
In psychrometry, wet-bulb temperature is a measure of enthalpy of moist air, so that in the Psychrometric chart,
1. the constant enthalpy lines are also constant wet bulb temperature lines
2. the wet bulb and dry bulb temperature are same at any condition
3. the wet - bulb and dry-bulb temperature are equal at saturation condition.
Of these statements.
(a) 1 alone is correct (b) 1 and 2 are correct
(c) 1 and 3 are correct (d) 2 and 3 are correct.

IES-37Ans. (c)

IES-38. Which one of the following statements is correct? [IES-1994]
(a) Pressure and temperature are independent during phase change.
(b) An isothermal line is also a constant pressure line in the wet vapour region.
(c) Entropy decreases during evaporation.
(d) The term dryness fraction is used to specify the fraction by mass of liquid in a mixture of liquid and vapour.
IES-38Ans. (b)

IES-39. In a psychrometric chart, what does a vertical downward line represent?
(a) Sensible cooling process (b) Adiabatic saturation process
(c) Humidification process (d) Dehumidification process **[IES-2009]**
IES-39Ans. (d)

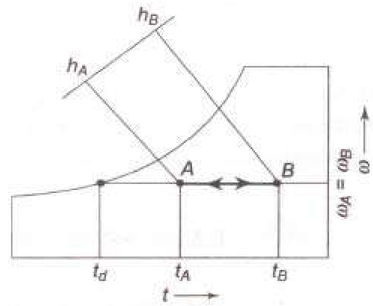
Basic Processes in Conditioning of Air

Sensible heating

IES-40. Consider the following statements: [IES-1994]
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
IES-40Ans. (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

IES-41. Consider the following statements regarding Psychrometric processes:
1. Sensible heating is a process in which moisture content remains unchanged.
2. In the dehumidification process the dew point temperature remains same.
3. The process of adding moisture at constant dry bulb temperature is known as pure humidification process.
Which of the statements given above is/are correct? [IES-2008]
(a) 1 and 2 (b) 1 and 3 (c) 2 and 3 (d) 1 only
IES-41Ans. (b) In the dehumidification process the dew point temperature decreases.

IES-42. Which one of the following is correct? [IES-2008]
In a sensible heating or cooling process
(a) dry bulb temperature remains constant
(b) wet bulb temperature remains constant
(c) the humidity ratio remains constant
(d) the relative humidity remains constant
IES-42Ans. (c)



Sensible Heat Process-Heating or Cooling

IES-43. Match List-I with List-II and select the correct answer using the code given below the lists: [IES-2008]

List I (Devices)	**List II (Process undergone by air)**
A. Cooling tower	**1. Heating**
B. Air coolers	**2. Cooling and dehumidification**
C. Evaporator coil	**3. Cooling and humidification**
D. Air cooled condenser	**4. Heating and humidification**

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

IES-43Ans. (b)

Cooling tower	→	Heating and humidification
Air coolers	→	Cooling and humidification
Evaporator coil	→	Cooling and dehumidification
Air cooled condenser	→	Heating

Sensible cooling

IES-44. 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

IES-44Ans. (b) During sensible cooling of air, its wet bulb temperature decreases but dew point remains unchanged.

IES-45. During sensible cooling [IES-1992]

(a) Relative humidity remains constant
(b) Wet bulb temperature increases
(c) Specific humidity increases
(d) Partial pressure of vapour remains constant.

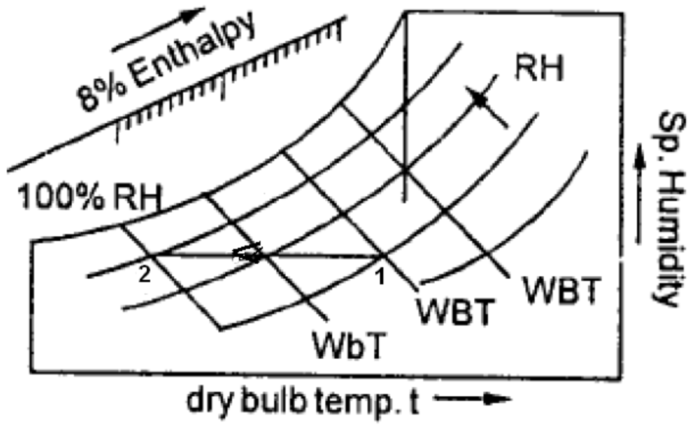
IES-45Ans. (d)

IES-46. Which one of the following is correct? [IES-2008]

During sensible cooling of moist air, its relative humidity

(a) increases (b) does not change
(c) decreases (d) affects specific humidity

IES-46Ans. (a)



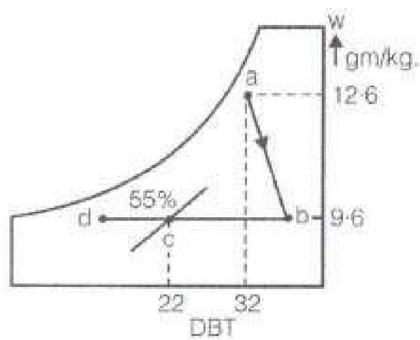
Humidification

Dehumidification

IES-47. 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

IES-47.Ans. (b) RH 100% constant remains.

IES-48.



A classroom is to be air-conditioned by obtaining the comfort conditions of 22°C dbt and 55% RH from outdoor conditions of 32°C dbt and 22°C wbt. The weight of outside air supplied is 30 kg/min. The comfort conditions required are achieved first by chemical dehumidification and then by cooling with a cooling coil as shown in the psychrometric chart above. What is the capacity of the dehumidification in kg/hr? [IES-2009]
(a) 3.2 (b) 5.4 (c) 6.8 (d) 9.5

IES-48Ans. (b) Capacity of dehumidification in kg hour

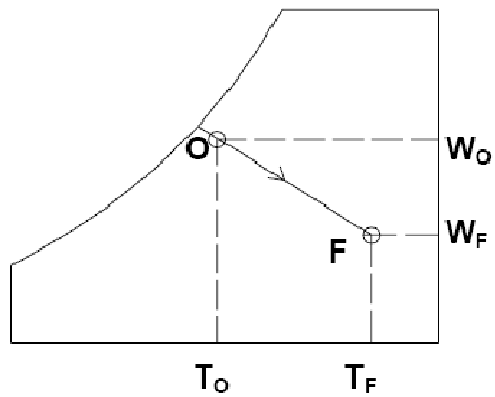
$$= m \times (\omega_1 - \omega_2)$$

$$= (30 \times 60)(12.6 - 9.6) \times 10^{-3} = 5.4 \text{ kg / hour}$$

Chemical Dehumidification

IES-49. 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

IES-49Ans. (d) The absorption of water by the hygroscopic material is an exothermic reaction, as a result heat is released during this process, which is transferred to air and the enthalpy of air increases.



IES-50. If air is passed through a solid chemical absorbent, the Psychrometric process followed is [IES-1992]
(a) heating and dehumidification with the wet 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.

IES-50.Ans. (a)

Cooling and dehumidification

IES-51. 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? [IES-2004]
(a) Cooling and humidification (b) Sensible cooling
(c) Cooling and dehumidification (d) Heating and humidification

IES-51Ans. (c) As temp of shower (20^0C) is below DBT (35^0C) sensible cooling will occur.
As temp of the shower (20^0C) is below Dew point temp (25^0C) some moisture of will condensed and form water droplets i.e. dehumidification.

IES-52. For cooling and dehumidifying of unsaturated moist air, it must be passed over a coil at a temperature [IES-2002]
(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

IES-52Ans. (b)

Cooling and humidification

IES-53. **Assertion (A):** During cooling with humidification dew point decreases.
Reason (R): The process results in increased specific humidity. **[IES-1992]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-53Ans. (d)

IES-54. **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** **[IES-1994]**
(a) cooled and humidified (b) cooled and dehumidified
(c) heated and humidified (d) heated and dehumidified

IES-54.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.

Heating and dehumidification

Sensible heat factor (SHF)

IES-55. **The sensible heat factor of a room is given by (S.H.L = Sensible heat load and L.H.L. = Latent heat load)** **[IES-1999]**

(a) $\frac{S.H.L - L.H.L}{S.H.L}$ (b) $\frac{S.H.L}{S.H.L - L.H.L}$ (c) $\frac{S.H.L + L.H.L}{S.H.L}$ (d) $\frac{S.H.L}{S.H.L + L.H.L}$

IES-55Ans. (d) $SHF = \frac{S.H.L}{S.H.L + L.H.L}$

IES-56. **What is the sensible heat factor during the heating and humidification process equal to?** **[IES-2006]**

(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

IES-56.Ans. (d)

IES-57. **The latent heat load in an auditorium is 25% of the sensible heat load. The value of sensible heat factor (S H F) is equal to** **[IES-2002]**
(a) 0.25 (b) 0.5 (c) 0.8 (d) 1.0

IES-57Ans. (c)

IES-58. 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 [IES-1993]

(a) 0.3 (b) 0.6 (c) 0.67 (d) 1.5

IES-58.Ans. (b) Sensible heat factor $= \dfrac{\text{sensible heat}}{\text{sensible heat + latent heat}} = \dfrac{30}{30+20} = 0.6$

Psychrometric Processes in Air Conditioning Equipment

Bypass factor

IES-59. 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

IES-59.Ans. (c)

IES-60. In order to have a low bypass factor of a cooling coil, the fin spacing and the number of tube rows should be: [IES-1998; 2005]

(a) Wide apart and high, respectively (b) Wide apart and low, respectively
(c) Close and high, respectively (d) Close and low, respectively

IES-60Ans. (c)

IES-61. 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

IES-61Ans. (a) Bypass factor $= \dfrac{t_3 - t_2}{t_3 - t_1} = \dfrac{45-40}{45-20} = 0.2$

IES-62. 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 [IES-1994]

(a) 0.375 (b) 0.4 (c) 0.6 (d) 0.67

IES-62.Ans. (c) Bypass factor of heating coil $= \dfrac{40-25}{40-15} = 0.6$

IES-63. In the case of sensible cooling of air, the coil efficiency is given by (BPF = Bypass factor) [IES-1993]

(a) BPF-1 (b) 1-BPF (c) BPF (d) 1 + BPF

IES-63Ans. (b) Coil efficiency in the sensible cooling is = 1 - BPF

IES-64. 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]**

IES-65Ans. (c) Let us take an example $t_3 - t_1 = 100°C$

First coil will reduce 30 °C Then only 70 °C left for next two coil

Second coil will reduce 30% of 70 °C i.e. 21 °C . Then only 49 °C left for third coil
Third coil will reduce 30% of 49 °C i.e. equal to 14.7 °C
Therefore total by pass = (100 – 30 – 21 – 14.7) = 34.3 °C

So $BPF = \frac{34.3}{100} = 0.343$

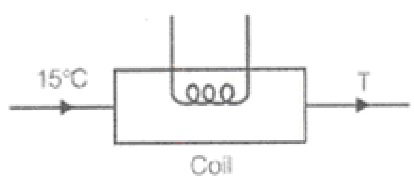
IES-66. By pass factor for a cooling coil **[IES-1992]**
(a) increases with increase in velocity of air passing through it
(b) decrease with increase in velocity of air passing through it
(c) remains unchanged with increase in velocity of air passing through it
(d) may increase or decrease with increase in velocity of air passing through it depending upon the condition of air entering.

IES-66Ans. (a)

Heating Coil

IES-67. The atmospheric air at 760 mm of Hg, dry bulb temperature 15°C and wet bulb temperature 11°C enters a heating coil whose temperature is 41°C. If the by-pass factor of the heating coil is 0.5, then what will be the dry bulb temperature of the air leaving the coil? **[IES-2009]**
(a) 28°C (b) 29°C (c) 30°C (d) 26°C

IES-67Ans. (a) Let the D.B.T of leaving coil = T°C



Temperature = 41°C

$$\frac{41-T}{41-15} = 0.5$$

$$\Rightarrow \quad 41 - T = 13$$

$$\Rightarrow \quad T = 28°C$$

Air Washer

IES-68. 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

IES-68Ans. (d)

IES-69. 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
(c) Heating and dehumidification (d) Cooling and dehumidification

IES-69Ans. (d)

IES-70. 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

IES-70Ans. (b)

Air Conditioning

IES-71. For an air-conditioned space, RTH = 100 kW, RSHF = 0.75, volume flow rate = 100m³/min, and indoor design specific humidity is 0.01 kg/kg of dry air. What is the specific humidity of the supply air? [IES-2001; 2005]

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

IES-71.Ans.(c) $(\text{Cmm})_{s,\min} = \dfrac{\text{RLH}}{50(\omega_i - \omega_{\text{ADP}})}$ or $100 = \dfrac{25}{50(\omega_i - 0.01)}$ or $(\omega_i - 0.01) = 0.005$

$\left[\because \text{RSHF} = \dfrac{\text{RSH}}{\text{RTH}} = \dfrac{\text{RSH}}{\text{RSH} + \text{RLH}}\right]$

IES-72. Fresh air intake (air change per hour) recommended for ventilation purposes in the air-conditioning system of an office building is [IES-1997]

(a) 1/2 (b) 3/2 (c) 9/2 (d) 25/2

IES-72Ans. (d)

IES-73. 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? [IES-2005]

(a) 0.25 (b) 0.5 (c) 0.75 (d) 1.00

IES-73Ans. (b) $\text{RSHF} = \dfrac{\text{RSH}}{\text{RSH} + \text{RLH}} = \dfrac{50}{50 + 50} = 0.5$

IES-74. Assertion (A): Dehumidification and humidification respectively are needed in winter and summer air-conditioning. **[IES-1994]**

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.

(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-74.Ans. (a) Both A and R are true and R provides correct explanation for A.

Previous 20-Years IAS Answer

Specific humidity or Humidity ratio

IAS-1. The expression $\dfrac{0.622\,p_v}{p_b - p_v}$, where P_v = partial pressure of water vapour; P_b= atmospheric barometric pressure, is used for calculating **[IAS-2001]**

(a) relative humidity (b) degree of saturation
(c) humidity ratio (d) pressure of air

IAS-1Ans. (c) Specific humidity or absolute humidity or humidity ratio (w) = $0.622 \times \frac{p_v}{p_b - p_v}$

IAS-2. 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

IAS-2.Ans. (a) $\text{relative humidity}\left(Q\right) = \frac{P_V}{P_S} \times 100\% = \frac{0.01}{0.02} \times 100\% = 50\%$

$$\text{Specific humidity}\left(\mu\right) = 0.622\frac{P_V}{P_b - P_v} = 0.622 \times \frac{0.01}{1.01 - 0.01} = 0.00622$$

Relative humidity

IAS-3. If a sample of moist air of 50% relative humidity at atmospheric pressure is isothermally compressed to a pressure of two atmospheres, then [IAS-1999]

(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

IAS-3.Ans. (c)

IAS-4. 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 **[IAS-2007]**

IAS-4Ans. (b)

IAS-5. Match List I (Quantity) with List II (Measuring Device) and select the correct answer using the codes given below the Lists: [IAS-2002]

List I (Quantity)	**List II (Measuring Device)**
A. Engine speed	**1. Manometer**
B. Fuel heating value	**2. Tachometer**
C. Air velocity	**3. Hydrometer**
D. Relative humidity of air	**4. Calorimeter**
	5. Hygrometer

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

IAS-5Ans. (c)

IAS-6. 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 [IAS-1998]
(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

IAS-6.Ans. (b)

Dew point temperature

IAS-7. 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 **[IAS-1999]**
(d) less than dew point

IAS-7Ans. (d)

IAS-8. **Consider the following statements: [IAS-1995]**
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.
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

IAS-8.Ans. (a)

Degree of saturation

IAS-9. 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

IAS-9Ans. (d)

Wet Bulb Temperature (WBT)

IAS-10. If wet bulb depression is equal to the sum of range and approach of a cooling tower, then the water [IAS-1999]
(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.

IAS-10Ans. (c)

IAS-11. Consider the following statements: [IAS-2003]
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

IAS-11Ans. (a)

IAS-12. 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 [IAS-2000]
(a) Lewis number (b) Prandtl number (c) Schmidt number (d) Sherwood number

IAS-12Ans. (a) Le = 0.945

Adiabatic saturation of air and adiabatic saturation temperature

IAS-13. Water in an insulated evaporative cooler evaporates at the rate of 0.003 kg/s. Air flow rate is 1kg/s. What is the air temperature decrease if the specific heat of humid air is 1kJ/kg K and latent heat of water is 2500 kJ/kg?
(a) 2.5^0 C (b) 3.0^0 C (c) 7.5^0 C (d) 10^0C **[IAS-2004]**

IAS-13Ans. (c) Heat balance gives us

$$\dot{m}_a c_p \Delta T = \dot{m}_w \times L$$

$$or\ \Delta T = \frac{\dot{m}_w \times L}{\dot{m}_a \times c_p} = \frac{0.003 \times 2500}{1 \times 1} = 7.5^0 C$$

IAS-14. Total heat transfer from a wetted surface depends upon [IAS-2003]
(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

IAS-14Ans. (d) spontaneous process.

IAS-15. The main process which takes place in a desert-cooler is [IAS-2001]
(a) sensible cooling (b) dehumidification
(c) adiabatic saturation (d) cooling and dehumidification

IAS-15Ans. (c) In a desert-cooler water vaporize and latent heat of vaporization is cools the air. i.e. cooling and humidification.

IAS-16. Desert coolers are suitable for hot very dry outside conditions because
(a) water is recirculated in the spray **[IAS 1994]**
(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

IAS-16Ans. (c)

Psychrometric Chart

IAS-17. With respect to the following figure which shows four processes on the Psychrometric chart, match List I with List II and select the correct answer using the codes given below the lists: [IAS-1996]

List I	**List II**
A. Process RS	**1. Cooling and humidifying**
B. Process RT	**2. Sensible heating**
C. Process RU	**3. Cooling and dehumidifying**
D. Process RW	**4. Humidifying**

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

IAS-17Ans. (c)

IAS-18. Assertion (A): On the Psychrometric chart, constant enthalpy lines and constant wet bulb lines are the same. **[IAS-1995]**
Reason (R): For the same wet bulb temperature, the moisture content remains constant.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-18Ans. (c)

Basic Processes in Conditioning of Air

Sensible heating

IAS-19. Match List I with List II and select the correct answer using the codes given below the lists: [IAS-1996]

List I	**List II**
A. Steam spray into air	**1. Sensible cooling**
B. Air passing over a coil carrying steam	**2. Cooling and dehumidification**
C. Air passing over coil having temperature less than dew point	**3. Heating and humidification**
D. Air passing over a coil having Temperature above the dew point but below the wbt	**4. Sensible heating**

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

IAS-19Ans. (c)

IAS-20. 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.

IAS-20Ans. (b)

Sensible cooling

IAS-21. 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) 1and 3 (c) 3 and 4 (d) 2 and 4

IAS-21Ans. (d)

IAS-22. During chemical dehumidification [IAS-1996]
(a) wet bulb temperature constant but enthalpy changes
(b) dry bulb temperature remains constant
(c) both dew point and we bulb temperature remain constant
(d) enthalpy and web bulb temperature remain constant

IAS-22Ans. (d) But WBT will increases.

IAS-23. 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

IAS-23Ans. (b)

Heating and humidification

IAS-24. 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

IAS-24Ans. (d)

IAS-25. The process in a hot water spray washer maintained at a temperature of 40^{0}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

IAS-25Ans. (c)

Cooling and dehumidification

IAS-26. 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 [IAS 1994]
(a) cooling and dehumidification (b) dehumidification and pure sensible cooling,
(c) cooling and humidification (d) dehumidification
IAS-26Ans. (a)

IAS-27. To cool and dehumidify a stream of moist air, it must be passed over the coil at a temperature [IAS-1995]
(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
IAS-27Ans. (c)

Cooling and humidification

IAS-28. 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 [IAS-2001]
(a) sensible cooling (b) cooling and humidification
(c) cooling and dehumidification (d) adiabatic saturation
IAS-28Ans. (b) Apparatus due point = 12^0C

$$\therefore \text{minimum temperature expected} = 12\times(1-0.1) = 10.8^0 C$$

So the process is cooling and humidification as 9^0C is lower than 10.8^0C

IAS-29. 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 [IAS-1997]
(a) sensible cooling (b) cooling and dehumidification
(c) cooling and humidification (d)cooling at constant wet bulb temperature
IAS-29Ans. (c)

IAS-30. In order to cool and dehumidify a stream of moist air, it must be passed over a coil at a temperature [IAS-2004]
(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
IAS-30.Ans. (c)

Heating and dehumidification

Sensible heat factor (SHF)

IAS-31. 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 [IAS-1997]
(a) 4 kJ/min (b) 2 kJ/min (c) 1 kJ/min (d) 0.25 kJ/min

IAS-31Ans. (c) $SHF = \dfrac{SH}{SH + LH}$ or $0.8 = \dfrac{SH}{5}$ or $SH = 4\ kJ/min,\ LH = 1\ kJ/min$

IAS-32. 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 m³/min, then the sensible heat factor (SHF) for the auditorium is [IAS 1994]
(a) 0.27 (b) 0.40 (c) 0.73 (d) 0.95

IAS-32Ans. (c)

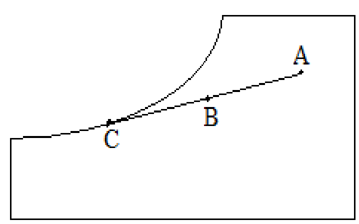
Psychrometric Processes in Air Conditioning Equipment

Bypass factor

IAS-33. Assertion (A): Bypass factor of a cooling coil decreases with decrease in face velocity.
Reason (R): Air gets more time to contact the cooling coil at lower face velocity.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[IAS-2003]**

IAS-33Ans. (b)

IAS-34. The condition of air for a cooling and dehumidification system is given by th point A at intake, B at discharge as marked on a Psychrometric chart. It C is the apparatus dew point, the bypass factor is given by



$(a)\dfrac{CA}{AB}$ $(b)\dfrac{CA}{BC}$ $(c)\dfrac{BC}{AB}$ $(d)\dfrac{BC}{CA}$

[IAS-1996]

IAS-34Ans. (d)

IAS-35. Consider the following statements [IAS 1994]
1. Low value of the bypass factor for an air-conditioning equipment signifies higher performance of the equipment
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

IAS-35Ans. (b)

Air Washer

IAS-36. Two steams moist air '1'and '2'mix together stream of unsaturated air '3', Let 'm' denote the rate of total mass flow of moist air, 'mω'denote the rate of mass flow of associated water vapour, 'ω'denote the specific humidity and 't' the temperature of a stream. Then 't_3' the temperature of stream '3' will be [IAS-1995]

(a) $\dfrac{(m_1 - m_{\omega 2})\omega_1 t_1 + (m_2 - m_{w2})\omega_2 t_2}{(m_3 - m_{\omega 3})\omega_3}$ (b) $\dfrac{(m_1 - m_{\omega 2})t_1 + (m_2 - m_{w2})t_2}{(m_3 - m_{\omega 1})}$

(c) $\dfrac{\omega_1 t_1 + \omega_2 t_2}{\omega_2}$ (d) $\dfrac{m_1\omega_1 t_1 + m_2\omega_2 t_2}{m_2\omega_3}$

IAS-36Ans. (b)

Air Conditioning

IAS-37. 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

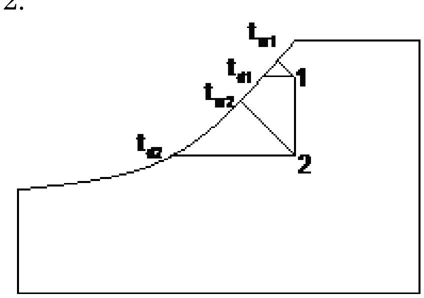
Which of these statements are correct?

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

IAS-37 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 $h_2 = h_1 + (\omega_2 - \omega_1)h_f$

4. See above graph

So 2 & 4 are correct

IAS-38. 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

IAS-38Ans. (b)

IAS-39. 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

IAS-39Ans. (d)

IAS-40. The state of air supplied by a cooling coil with a by-pass factor X lies on the Psychrometric 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 (I-X)

IAS-40Ans. (d)

IAS-41. Consider the following statements related to all-air air-conditioning system:
1.All air system uses air as heating or cooling fluid. [IAS-2007]
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

IAS-41Ans. (c)

10. Miscellaneous

OBJECTIVE QUESTIONS (GATE, IES, IAS)

Previous 20-Years GATE Questions

Load calculation

GATE-1. 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 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 [GATE-2007]

(a) 75.0 (b) 123.8 (c) 128.2 (d) 159.0

GATE-1Ans. (c) W_1 = 19 gram /kg of dry air

=19 × 10^{-3} kg / kg of dry air

W_2 = 8 gram / kg of dry air

Hence at inlet mass of water vapour

= m_{v1} = 19 × 10^{-3} × (3kg / sec)

= 57 × 10^{-3} kg / sec.

At out let mass of water vapour

M_{v1} = 8 × 10^{-3} × (3 kf / sec)

= 24 × 10^{-3} kg / sec.

Hence mass of water condensed

= (57 – 24) ×kg/sec.

Reqd.cooling capacity = change in enthalpy of condensed water +change in enthalpy of dry air

= (67 KJ / kg) × 33 × 10^{-3} kg / sec + (85 KJ/ kg) – 43 KJ/kg) × 3 kg /sec

=128.211 KW

Solar refrigeration

GATE-2. 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 [GATE-2004]

(a) 8.33 m² (b) 16.66 m² (c) 39.68 m² (d) 79.36 m²

GATE-2Ans. (d)

Let area be A $\therefore$ heat received(G) = 0.6A kW

and power given to the fluid(Q) = $G \times \varepsilon = 0.6A \times 0.5 = 0.3A$ kW

Maximum efficiency is Carnot Efficiency $(\eta) = 1 - \frac{313}{350} = 0.10571$

$\text{Power deliver}(W) = Q \times \eta$

Or $2.5 = 0.3A \times 0.10571$ or $A = 79.36\,m^2$

Duct Design

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 n 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/m^3. The laminar flow Nusselt number is 3.4 for constant wall temperature conditions and, for turbulent flow, Nu = 0.023 Re$^{0.8}$Pr$^{0.8}$

GATE-3. The Reynolds number for the flow is [GATE-2005]

(a) 444 (b) 890 (c) 4.44 x 10^5 (d) 5.33 x 10^5

GATE-3Ans. (c)

$$R_e = \frac{\rho v D}{\mu}, \qquad \left[D = \frac{4A_c}{P} = \frac{4 \times 1 \times 0.5}{2(1+0.5)} = 0.6667\right]$$

$$\text{Or } R_e = \frac{1.2 \times 10 \times 0.6667}{18 \times 10^{-6}} = 4.444 \times 10^5$$

GATE-4. The heat transfer per metre length of the duct, in watts, is [GATE-2005]

(a) 3.8 (b) 5.3 (c) 89 (d) 769

GATE-4Ans. (d)

$$\bar{N}u = 0.023 \times (R_e)^{0.8} \times (0.73)^{0.33} = 683.72$$

$$\bar{N}u = \frac{\bar{h}D}{k} \text{ or } \bar{h} = \frac{683.72 \times 0.025}{0.6667} = 25.64$$

$$Q = \bar{h}A(t_h - t_c) = 25.64 \times 2 \times (1+0.5) \times 1 \times (30-20) = 769\,W/m$$

Previous 20-Yrs IES Questions

Comfort

IES-1. 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

IES-1Ans. (d)

IES-2. A human body feels comfortable when the heat produced by the metabolism of human body is equal to [IES-1993; 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)

IES-3Ans. (c)

IES-4. A human body feels comfortable when the heat produced due to metabolism of human body is equal to the [IES-1999]
(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

IES-4Ans. (d)

IES-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

IES-5Ans. (b)

IES-6. On which factor(s), does the heat lost by the human body in the process of radiation depend? [IES-2005]
(a) Temperature only (b) Temperature and air motion
(c) Temperature and relative humidity (d) Relative humidity and air motion

IES-6Ans. (a)

IES-7. Which of the following are normally desired comfort conditions in an air-conditioning system? [IES-2004]
(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

IES-7Ans. (a)

IES-8. The desirable air velocity in the occupied zone for comfort for summer air-conditioners is in the range of [IES-2000]
(a) 6 - 7 m/minute (b) 4 - 5 m/minute (c) 2 - 3 m/minute (d) 0.5 - 1.5 m/minute

IES-8Ans. (a) The recommended comfort conditions for different seasons and clothing suitable at 50% RNH, air velocity of 0.15 m /s and an activity level of ≤ 1.2 met.

Season	Clothing	I_{cl}	$T_{op,opt}$	T_{op} range for 90% acceptance
Winter	Heavy slacks, long sleeve shirt and sweater	0.9 clo	22^0C	20 to 23.5 ^{0}C
Summer	Light slacks and short sleeve shirt	0.5 clo	24.5^0C	23 to 26^0C
	Minimal (shorts)	0.05 clo	27. ^{0}C	26 to 29^0C

0.15 m/s = 9 m/minute

IES-9. The reason for a person feeling more comfortable on a warm day if seated in front of an electric fan is that the [IES-1999]
(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

IES-9Ans. (b)

IES-10. On a summer day, a scooter rider feels more comfortable while on the move than while at a stop light because [IES-1998]
(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.

IES-10Ans. (c)

IES-11. What are the general comfort conditions in an air-conditioning system? [IES-2006]
(a) 20°C DBT, 80% RH (b) 24°C DBT, 60% RH
(c) 25°C DBT, 40% RH (d) 25°C DBT, 100% RH

IES-11Ans. (b) ASHARE makes the following recommendations:
Inside design conditions for Winter:
$T_{optimum}$ between 20.0 to 23.5°C at a RH of 60%
$T_{optimum}$ between 20.5 to 24.5°C at a DPT of 2°C
Inside design conditions for Summer:
$T_{optimum}$ between 22.5 to 26.0°C at a RH of 60%
$T_{optimum}$ between 23.5 to 27.0°C at a DPT of 2°C

IES-12. Which of the following statements are correct? [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

IES-12Ans. (a)

Effective temperature

IES-13. The effective temperature is a measure of the combined effects of **[IES-1998]**
(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

IES-13Ans. (d) The effective temperature is the combined effect of dry bulb temperature, relative humidity and air motion.

IES-14. Effective temperature is that temperature of saturated air which gives the same degree of comfort as the air at given [IES-1993]
(a) DBT, WBT and incidental solar radiation
(b) WBT, incidential solar radiation and air flow rate
(c) DBT, sol-air temperature and air flow rate
(d) DBT, WBT and air flow rate

IES-14Ans. (d)

IES-15. Effective temperature depends on dry bulb temperature, and **[IES-2006]**
(a) Wet bulb temperature only (b) Relative humidity
(c) Specific humidity (d) Wet bulb temperature and air motion

IES-15Ans. (d)

IES-16. 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? [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

IES-16Ans. (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
$\Delta t = - 0.1276\ (6 - 20) = - 1.8\ ^{o}C$

IES-17. Which one of the following statements is correct? [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

IES-17Ans. (b)

IES-18. Which one of the following statements is correct? [IES-2004]
(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

IES-18Ans. (a)

IES-19. Upon which of the following factors does the effective temperature for human comfort depend? [IES-2003]
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

IES-19Ans. (d) Important factors are the dry bulb temperature, relative humidity, air motion and surrounding surface temperature. Of these the dry bulb temperature affects heat transfer by convection and evaporation, the relative humidity affects heat loss by evaporation, air velocity influences both convective and evaporative heat transfer and the surrounding surface temperature affects the radiative heat transfer.

IES-20. Consider the following parameters: [IES-2000]
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

IES-20Ans. (d)

IES-21. **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. **[IES-2001]**
Reason (R): Comfort does not depend on humidity and air velocity.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-21Ans. (c) Comfort depends on dry bulb temp, humidity and air velocity.

Load calculation

IES-22. **The heat load from the occupants in air-conditioning load calculation is a source of:** **[IES-2006]**
(a) Sensible heat only (b) Latent heat only
(c) Both sensible and latent heat (d) None of the above

IES-22Ans. (c)

IES-23. **An air-conditioned room of volume 10 m³ has infiltration of air equivalent to 3 air changes per hour. 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. What is the sensible heat load due to infiltrated air?** **[IES-2005]**
(a) 60 kJ/hour (b) 12 kJ/hour (c) 0.45 kW (d) 0.2 kW

IES-23Ans. (d) $Q = mc_p\Delta t = \left\{\left(\frac{10\times 3}{3600}\right)\times 1.2\right\}\times 1\times 20 = 0.2\text{kW}$

IES-24. **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** **[IES-2001; 2003]**
(a) 734 kW (b) 12.24 kW (c) 0.204 kW (d) 10 kW

IES-24Ans (b) Infiltration '1' air change per hour, i.e., (cmm) = $\frac{20\times 30\times 4}{60} m^3/\min$

[(cmm) = volumetric flow rate cubic meter per minute]

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

IES-25. **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** **[IES-2000]**
(a) 60 kJ/hr (b) 12 kJ/hr (c) 6 kW (d) 0.2 kW

IES-25Ans. (d)

IES-26. **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 of16°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** **[IES-2003]**
(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

IES-26Ans. (c) We know that humid specific heat, $C_p = C_{pa}+\omega C_{pv}$ = 1.02 KJ/kgda.K

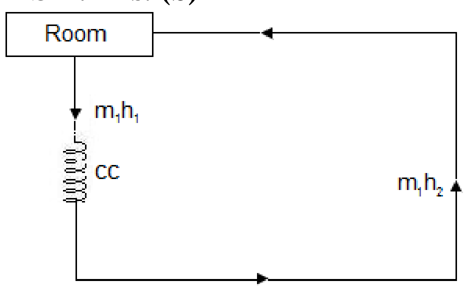
Therefore, Sensible heat load (SHL) = $m_a C_p \left(\Delta T_{db}\right) = 10\times1.02\times(30-16) = 142.8kW$

and Latent heat load (LHL) = $m_a\left(\omega_i-\omega_o\right)\left(h_{fg}\right) = 10\times\left(0.017-0.008\right)\times2500 = 225\,kW$

IES-27. 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? [IES-2004]

(a) 80 kJ/kg (b) 90 kJ/kg (c) 100 kJ/kg (d) 102.5 kJ/kg

IES-27Ans. (b)



$\therefore Q = m_1\left(h_1 - h_2\right)$

or $h_1 = h_2 + \dfrac{Q}{m_1} = 40 + \dfrac{100\times 210\,kJ/min}{420\,kg/min} = 90\,kJ/kg$

IES-28. 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, [IES-2002]

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

IES-28Ans. (d)

IES-29. Consider the following statements: [IES-2000]
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

IES-29Ans. (d) In order to find the required cooling capacity of the system, one has to take into account the sensible and latent loads due to ventilation, leakage losses in the return air ducts and heat added due to return air fan. Typical outdoor (OD) air requirement for the purpose of ventilation:

Function	Occupancy per 100m floor area	OD air requirement per person (L /s)	
		Smoking	Non-smoking
Offices	7	10	2.5

Operation theatres	20	-	15
Lobbies	30	7.5	2.5
Class rooms	50	-	8.0
Meeting places	60	17.5	3.5

IES-30. In air-conditioning design for summer months, the condition inside a factory where heavy work in performed as compared to a factory in which light work is performed should have [IES-1998]
(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

IES-30Ans. (a)

IES-31. 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 [IES-1995]
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.

IES-31Ans. (b)

IES-32. Consider the following factors: [IES-1994]
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.

IES-32Ans. (d) Occupancy load in cooling load calculation depend upon type of activity and indoor design conditions.

Solar refrigeration

IES-33. What is Sol-air temperature? [IES-2006]
(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

IES-33Ans. (a) sol-air temperature $t_e = t_o + \frac{\alpha I}{h_o}$

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

For heat transfer through building structure the sol-air temperature is used instead of conduction and solar radiation separately.

IES-34. On which of the following factors does sol-air temperature depend?
1. Outdoor air temperature **[IES-2003]**
2. Intensity of solar radiation
3. Absorptivity of wall
4. Convective heat transfer coefficient at outer surface of wall
5. Indoor design temperature
Choose the correct answer from the codes given below:
(a) 1, 2 and 5 (b) 1, 2 and 3 (c) 3 and 4 (d) 1, 2, 3 and 4

IES-34Ans. (d)

IES-35. 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]**

IES-35Ans. (b) Heat absorbed = heat dissipated or $G.A = h \times (2A) \times \Delta t$

$$\text{or } 500 = h \times 2 \times (30 - 25) \quad \text{or } h = \frac{500}{2 \times 5} = 50\, W/m^2.k$$

IES-36. Assertion (A): In an air-conditioned room, the reflective coating should be on the inside of the window.
Reason (R): plane Window glass is transparent to solar radiation. **[IES-1996]**
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IES-36Ans. (d) A is false but R is true

Duct Design

IES-37. Which one of the following is correct? [IES-2008]
Equal friction method of designing ducts is preferred
(a) when system is balanced
(b) when system is not balanced
(c) only for return ducts
(d) for any system

IES-37Ans. (a)
- In the equal friction method, the frictional pressure drop per unit length of the duct is maintained constant throughout the duct system.
- The method is generally recommended because of its simplicity.
- If an equal friction design has a mixture of short and long runs of duct, the shortest duct will need a considerable amount of dampering. This is a drawback of the equal friction design.
- Equal friction method of designing ducts is preferred when system is balanced.

IES-38. Which of the following method (s) is/are adopted in the design of air duct system? **[IES-1998]**
1. Velocity reduction method
2. Equal friction method

3. Static regain method.
Select the correct answer using the codes given below:
Codes:
(a) 1 alone (b) 1 and 2 (c) 2 and 3 (d) 1, 2 and 3

IES-38Ans. (c)

IES-39. 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 region method (d) dual or double duct method.

IES-39Ans. (b) Equal friction method is simple and is most widely used conventional method. This method usually yields a better design than the velocity method as most of the available pressure drop is dissipated as friction in the duct runs, rather than in the balancing dampers. This method is generally suitable when the ducts are not too long, and it can be used for both supply and return ducts.

IES-40. 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

IES-40Ans. (b)

IES-41. Which one of the following statements is true for air conditioning duct design? **[IES-2001]**
(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-41Ans. (c)

IES-42. If coefficient of contraction at the vena contracta is equal to 062, then what will be the dynamic loss coefficient in sudden contraction in air-conditioning duct? **[IES-2004]**
(a) 0.25 (b) 0.375 (c) 0.55 (d) 0.65

IES-42Ans. (b) $K = \left(\frac{1}{C_c} - 1\right)^2 = \left(\frac{1}{0.62} - 1\right)^2 = 0.375$

IES-43. 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

IES-43Ans. (d)

IES-44. Consider the following statements: [IES-2000]
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

IES-44Ans. (b)

IES-45. 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) $D = \frac{2ab}{a+b}$

IES-45Ans. (d)

IES-46. Air enters a rectangular duct measuring 30 x 40 cm with a velocity of 8.5 m/s and a temperature of 40°C. Kinematic viscosity of the air is 16.95 x 10^{-6} m^2/s. What will be the Reynolds number? [IES-2009]

(a) 1.72 x 10^5 (b) 2.58 x 10^5 (c) 0.86 x 10^5 (d) 0.72 x 10^5

IES-46Ans. (a)

$$L_C = \frac{2ab}{a+b}$$
$$= \frac{2\times 0.3\times 0.4}{(0.3+0.4)} = 0.342$$
$$R_e = \frac{VL_C}{\nu} = \frac{8.5\times 0.342}{16.95\times 10^{-6}}$$
$$= 171934.26 = 1.72\times 10^5$$

IES-47. Instantaneous cooling loads are NOT equal to instantaneous heat gains because [IES-2003]

(a) Heat gains are offset by cooling provided by the AC system
(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

IES-47Ans. (d)

Previous 20-Years IAS Answer

Comfort

IAS-1. Assertion (A): The actual inside design temperatures selected in comfort air-conditioning are not necessarily those conditions of optimum comfort. **[IAS-2001]**

Reason (R): The length and type of occupancy, the outside design conditions and economic factors affect the choice.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is **not** the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

IAS-1Ans. (d) A is false but R is true
The required inside design conditions depend on the intended use of the building. Air conditioning is required either for providing suitable comfort conditions for the occupants (e.g. comfort air conditioning), or for providing suitable conditions for storage of perishable products (e.g. in cold storages) or conditions for a process to take place or for products to be manufactured (e.g. industrial air conditioning). The required inside conditions for cold storage and industrial air conditioning applications vary widely depending on the specific requirement. ***However, the required inside conditions for comfort air conditioning systems remain practically same irrespective of the size, type, location, use of the air conditioning building etc., as this is related to the thermal comfort of the human beings.***

IAS-2. 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 **[IAS-1997]**
(c) 2 to 3^{0}C above the room temperature
(d) at 0° C

IAS-2Ans. (b)

IAS-3. The difference between the comfort airconditioning and industrial airconditioning lies in the [IAS-1998]
(a) equipment used (b) process adopted
(c) indoor requirements (d) ambient conditions

IAS-3.Ans. (c)

Effective temperature

IAS-4. 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
(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. **[IAS-2004]**

IAS-4.Ans. (c) Rule: Any activity which reduces comfort will increase ET.

IAS-5. Consider the following statements: [IAS-1999]
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

IAS-5.Ans. (b)

IAS-6. Consider the following statements: [IAS-1996]
Effective temperature
1. Is a measure of the sensation of warmth or coldness.
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

IAS-6Ans. (a)

IAS-7. A room air is at a DBT of T_r and relative humidity ϕ_r . The effective temperature of the room is [IAS 1994]
(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
(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

IAS-7Ans. (a)

Duct Design

IAS-8. 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

IAS-8Ans. (a)

IAS-9. Match List I with List II and select the correct answer using the codes given below the lists:

List I (Material)	**List II (Purpose/application)**
A. Glass wool	**1. Cold storage**
B. Ammonia	**2. Domestic refrigerators**
C G.I. Sheet	**3. Insulation**
D. Polyurethane	**4. Ducting [IAS-1995]**

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

IAS-9Ans. (a)

IAS-10. 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

IAS-11Ans. (c)

IAS-12. For air-conditioning the operation theatre in a hospital, the percentage of outside air in the air supplied is [IAS-1995]
(a) zero (b) 20 (c) 50 (d) 100

IAS-12Ans. (d) It is advisable to recalculate infected air of operation theatre and accordingly % age of outside air is 100%.