GATE EXAMINATION QUESTIONS

UNIT-I

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-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°C and 75°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

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

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)

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

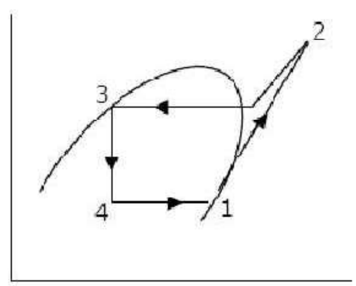
IES-6. Ans. (d)

UNIT-II

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)

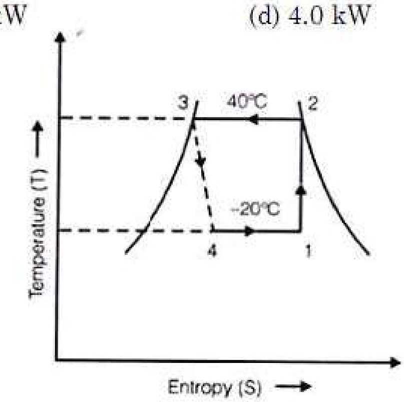
Data for Q3–Q4 are given below. Solve the problems and choose correct answers.

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

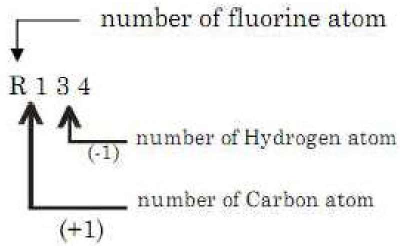
Refrigerant effect = $m(h_1 - h_2) = 0.025(164 - 80)$ = 2.1 KW

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

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

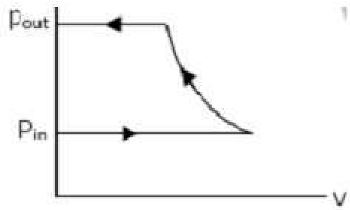
GATE-2. The use of Refrigerant –22 (R-22) for temperatures below –30°C is not recommended due to its **[GATE-1993]**
(a) Good miscibility with lubricating oil
(b) Poor miscibility with lubricating oil
(c) Low evaporating pressure
(d) High compressor discharge temperature

GATE-2. Ans. (d)

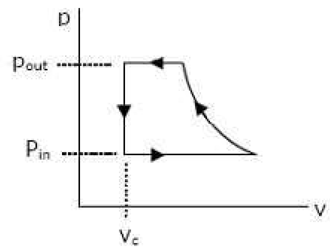
Types of Compressors

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

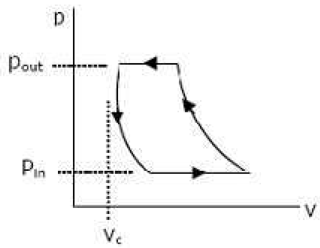
(a)



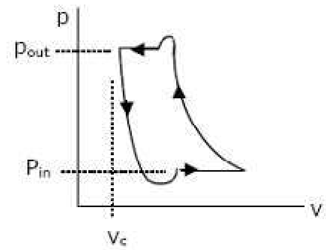
(b)



(c)



(d)



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

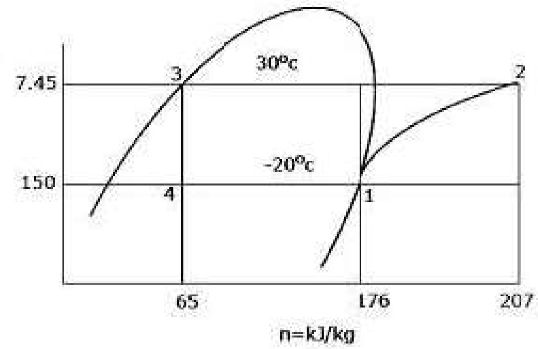
GATE-8. Clearance volume of a reciprocating compressor is 100 ml, and the volume of the cylinder at bottom dead centre is 1.0 litre. The clearance ratio of the compressor is: [GATE-1997]

(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 × 0.1089 = 6.89×10^{-3} m³/s

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

∴ 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) $W_{ideal} = \frac{\gamma}{\gamma-1}(P_1V_1 - P_2V_2) = \frac{\gamma}{\gamma-1} P_1V_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{(\gamma-1)}{\gamma}} - 1\right]$

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

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

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

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)

UNIT-4

Simple Vapour Absorption System

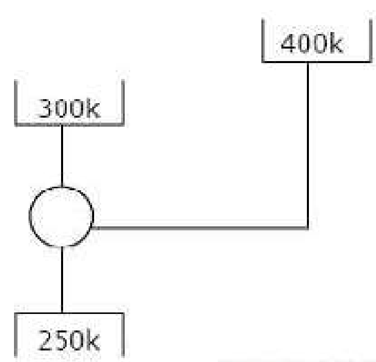
GATE-1. **[GATE-1997]**

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

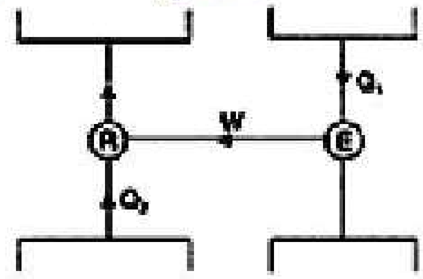


[GATE-2005]

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

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

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

$$\Rightarrow \quad 5 = \frac{Q_2}{W}$$

$$\therefore \quad W = \frac{Q_2}{5} \quad ...(ii)$$

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

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.

UNIT-5

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

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

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

$$= 0.01291 \text{ kg / kg of dry air}$$

enthalpy $(h) = 1.022\, t_d + W\,(h_{fgdp} + 2.3\, t_{dp})$

$$= 1.022 \times 30 + 0.01291\,(2500 + 2.3 \times 18)$$

$$= 1.022 \times 30 + 32.809$$

$$= 63.47 \text{ kJ / kg of dry air}$$

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,

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

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

$P_v = 1.62 \text{KPa}$

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

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, $\phi = \dfrac{P_v}{P_s}$

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

$(P_s)_{35^\circ c} = 0.05628 \text{bar}$

$\omega = 0.622 P_v$

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

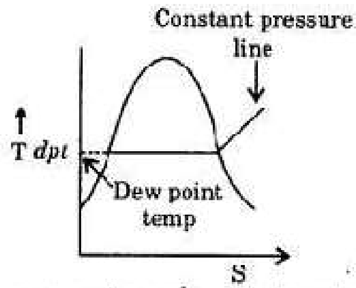
GATE-4Ans. (a, c)

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

Psychrometric Chart

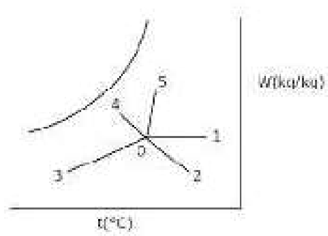
GATE-7. The statements concern Psychrometric chart. **[GATE-2006]**

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, $t_{water\ spray} > t_{DBT}$ so heating and humidification.

Cooling and dehumidification

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

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°C (B) 20°C (C) 25°C (D) 30°C **[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°C in an after cooler. The air at the entry to the after cooler is

unsaturated and becomes just saturated at the exit of the after cooler. The saturation pressure of water at 35°C is 5.628 kPa. The partial pressure of water vapour (in kPa) in the moist air entering the compressor is closest to [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= $\frac{5.628}{5} = 1.1256 \cong 1.13 kPa$

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)

UNIT-6

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

$= 19 \times 10^{-3}$ kg / kg of dry air

W_2 = 8 gram / kg of dry air

Hence at inlet mass of water vapour

$= m_{v1} = 19 \times 10^{-3} \times$ (3kg / sec)

$= 57 \times 10^{-3}$ kg / sec.

At out let mass of water vapour

$M_{v1} = 8 \times 10^{-3} \times$ (3 kf / sec)

$= 24 \times 10^{-3}$ 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 $(\eta) = 1 - \dfrac{313}{350} = 0.10571$

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/m³. 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 10⁵ (d) 5.33 x 10⁵

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)

$$\bar{N}u = 0.023 \times (R_e)^{0.8} \times (0.73)^{0.33} = 683.72$$

$$\bar{N}u = \frac{\bar{h}D}{k} \text{ or } \bar{h} = \frac{683.72 \times 0.025}{0.6667} = 25.64$$

$$Q = \bar{h}A(t_h - t_c) = 25.64 \times 2 \times (1+0.5) \times 1 \times (30-20) = 769\ W/m$$