

## MECHANICAL ENGINEERING Paper I

Time Allowed: Three Hours

Maximum Marks: 250

## Question Paper Specific Instructions

*Please read each of the following instructions carefully before attempting questions*

*There are **EIGHT** questions divided in **TWO SECTIONS** and printed both in **HINDI** and in **ENGLISH**.*

*Candidate has to attempt **FIVE** questions in all.*

*Questions no. 1 and 5 are compulsory and out of the remaining, any **THREE** are to be attempted choosing at least **ONE** question from each section.*

*The number of marks carried by a question /part is indicated against it.*

*Answers must be written in the medium authorized in the Admission Certificate which must be stated clearly on the cover of this Question-cum Answer (QCA) Booklet in the space provided. No marks will be given for answers written in a medium other than the authorized one.*

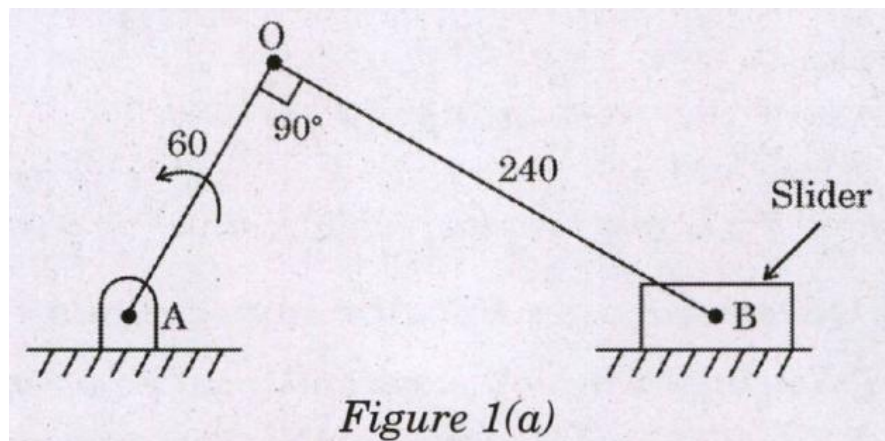
*Wherever any assumptions are made for answering a question, they must be clearly indicated. Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.*

*Unless otherwise mentioned, symbols and notations carry their usual standard meanings.*

*Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer (QCA) Booklet must be clearly struck off.*

## SECTION A

- Q1.** (a) A slider-crank mechanism with crank radius 60 mm and connecting rod length 240 mm is shown in Figure 1(a). The crank is rotating with a uniform angular speed of 10 rad/s, counterclockwise. For the given configuration, determine the speed of the slider. A and B in Figure 1(a) are at the same horizontal level. 10



- (b) In a complex two-dimensional stress system, the maximum and minimum principal stresses are found to be 160 MPa tensile and 80 MPa compressive. The material elastic limit is 300 MPa in a simple tension test. Find factor of safety using the following theories: 10
- Maximum principal stress theory.
  - Maximum shear stress theory.
  - Maximum distortion energy theory.
- (c) A pipe with external forces is shown in Figure 1(c). The loads 300 N, 200 N, and 900 N are acting at the centres of pipe sections as shown in the figure. Find the resultant of force system at point A shown in the figure. 10

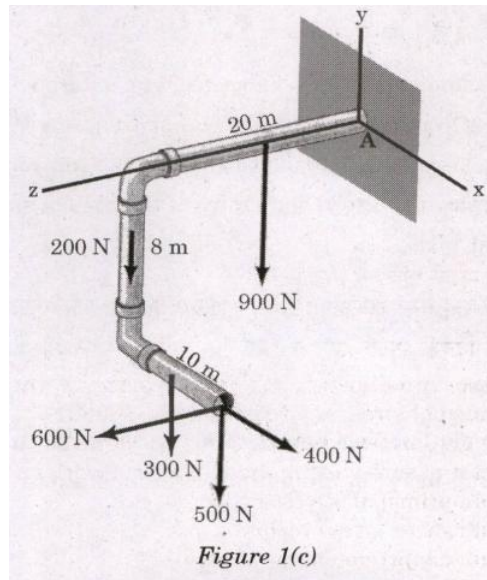


Figure 1(c)

- (d) Compare thermosetting and thermoplastic types of plastics in terms of properties, response to heating and applications. 10
- (e) Two meshing spur gears with pressure angle of the involute teeth being  $20^\circ$  have addendum equal to one module. The pinion has 14 teeth and the larger gear has 54 teeth. Does the interference occur? If it occurs, what should be the change in the pressure angle in order to eliminate interference? Take standard module = 10 mm. 10
- Q2.** (a) A 20 mm diameter shaft is subjected to a torque of 80 Nm and a downward bending moment of 100 Nm at the centre. Draw the state of stress on the bottom surface of the shaft at the centre and find principal stresses and shear stress at the centre of the bottom surface. What is the angle of shear plane? 15
- (b) What is Atomic Packing Factor of a crystal structure? Calculate the atomic packing factor of aluminium assuming atoms to be of spherical shape with atomic radius ' $R$ '. 15
- (c) The cranks of a three-cylinder single acting engine are set equally at  $120^\circ$ . The engine speed is 540 rpm. The turning moment diagram for each cylinder is a triangle for the power stroke with a maximum torque of 100 Nm at  $60^\circ$  after dead-centre of the corresponding crank. On the return stroke, the torque is sensibly zero. Determine the: 20
- power developed by the engine.
  - coefficient of fluctuation of speed if the flywheel has a mass of 7.5 kg with a radius of gyration of 65 mm.
  - coefficient of fluctuation of energy.
  - maximum angular acceleration of the flywheel.
- Q3.** (a) A thin cylinder of diameter 200 mm and length 1000 mm is subjected to an internal pressure of 10 MPa. The allowable stress of the material is 200 MPa and Young's modulus is 200 GPa. Determine the thickness, hoop and longitudinal strains under the given pressure. 10
- (b) A beam carries a uniformly distributed load of 360 N/m over the entire span together with a concentrated load of 400 N at the extreme left. The beam is having a span of 10 m and is supported at two points 7 m apart. The supports

are so chosen, that each support carries half the total load.

Draw the shear force and bending moment diagrams after obtaining the maximum bending moment and points of contraflexure. 20

- (c) In a Hartnell governor, the lengths of ball and roller arms of the bell crank lever are 100 mm and 80 mm respectively. Each ball has a mass of 1.5 kg. The extreme radii of rotation of the balls are 90 mm and 140 mm. The minimum equilibrium speed is 840 rpm and the maximum equilibrium speed is 5% greater than this. Assuming the sleeve to be of negligible mass and neglecting friction and obliquity of arms, determine: 20
- Spring stiffness.
  - Initial compression of the central spring.
  - Equilibrium speed corresponding to radius of rotation of 130 mm.

- Q4.** (a) An automobile weighing 15 kN is moving at a speed of 100 km per hour. The dynamic coefficient of friction between the rubber tyre and concrete road is 0.60. When the driver jams on his brakes, the car goes into skid in the direction of motion. What is the distance the car will move before it comes to rest when 15
- the road is flat,
  - the road is  $7^\circ$  upward inclination,
  - the road is  $7^\circ$  downward inclination?
- (b) Explain the principle of annealing with the help of Continuous Cooling Transformation (CCT) diagram. Write the purpose and applications of annealing heat treatment. 15
- (c) A shaft carries four masses  $A$ ,  $B$ ,  $C$  and  $D$  which are in complete balance. Masses  $C$  and  $D$  make angles of  $90^\circ$  and  $210^\circ$  respectively with that of mass  $B$  in the counterclockwise direction. The rotating masses  $A$ ,  $B$ ,  $C$  and  $D$  can be assumed to be concentrated at radii of 360 mm, 480 mm, 240 mm and 300 mm respectively. The masses  $B$ ,  $C$  and  $D$  are 15 kg, 25 kg and 20 kg respectively and the planes containing  $B$  and  $C$  are 300 mm apart. Determine the following: 20
- Mass  $A$  and its angular position.
  - Positions of planes  $A$  and  $D$ .

### SECTION B

- Q5.** (a) An HSS drill during its life can drill 150 through holes in a 10 mm thick brass plate at a drill speed of 400 rpm. Another drill of same type can make only 75 holes when the drill speed is increased to 600 rpm. How many holes will be produced by another drill of same type if its speed is raised to 800 rpm? Take the feed in all the cases as same. 10
- (b) Write the functions of coating on Shielded Metal Arc Welding (SMAW) electrode. 10
- (c) Discuss the Expansionist strategy and Wait-and-See strategy for capacity timing and sizing concerning the capacity planning. 10
- (d) A product is to be processed from its raw form to finished form through a number of workstations. The production lead time is given as 3 days. The daily demand requirement is 500 units. Safety stock is required for one day. Container's capacity is 400 units. Determine the number of Kanbans (containers) required. 10

- (e) Derive the expression for Reorder point when demand is variable and lead time is constant. Suppose the average demand is 18 units per week with a standard deviation of 5 units. The lead time is constant at 2 weeks. Determine the safety stock and reorder point if management wants a 95% customer service level. (Refer Standard Normal Distribution table) 10

- Q6.** (a) During turning of a steel rod of 100 mm diameter, at a speed of 600 rpm, feed of 0.32 mm/rev and 3 mm depth of cut by a tool of the following geometry: inclination angle  $0^\circ$ , orthogonal rake angle  $-12^\circ$ , and principal cutting edge angle ( $\phi$ )  $60^\circ$ , the following have been observed:

Main cutting force component  $P_z = 1000$  N

Radial cutting force component  $P_y = 200$  N

Chip thickness = 0.75 mm

Using Merchant's theory, determine the force along the rake surface  $F$ , force acting perpendicular to the rake surface  $N$ , coefficient of friction between the chip-tool interface, shear force  $F_s$  and cutting power consumption. Power consumption due to feed motion may be neglected. 20

- (b) (i) State the sequence and purpose of different types of rolling passes, used for rolling flats and plates. 5
- (ii) A steel plate of 200 mm width and 30 mm thickness is rolled using two-stand rolling mill where diameter of each roller is 400 mm. Rolling is performed at 60 rev/min of roll speed to reduce thickness of steel strip from 30 mm to 26 mm. Average flow stress of metal during rolling is expressed by

$$\delta_f = \frac{K\varepsilon^n}{1+n},$$

where,  $n$  = strain hardening coefficient,

$K$  = strength coefficient, MPa,

$\varepsilon$  = true strain

Consider strength coefficient of metal ( $K$ ) is 300 MPa and strain hardening coefficient ( $n$ ) is 0.2 and coefficient of friction between strip and roll during rolling is 0.15.

Calculate:

(I) Draft in mm.

(II) Maximum achievable draft for above condition of rolling in mm.

(III) Average flow stress in MPa.

(IV) Rolling force in Newton.

(Neglect all other possibilities related to rolling) 15

- (c) Write the contributions of Walter A. Shewhart, W. Edwards Deming, Joseph M. Juran, Philip B. Crosby, and K. Ishikawa in the area of quality management. 10

- Q7.** (a) A firm has identified four operations, which are to be conducted in succession for an order to be processed. The tolerance and mean time of each operation are given in the following table. Tolerance is independent of each other and the time is normally distributed.

Operation	Mean Time (hours)	Tolerance (hours)
1	7	$7 \pm 0.6$
2	5	$5 \pm 0.6$

3	9	$9 \pm 0.8$
4	6	$6 \pm 0.3$

- (i) Find the natural tolerance limits for order completion time.
- (ii) If the company sets a goal of 27.5 hours, what proportion of the orders will fail to satisfy the goal?
- (iii) Find an appropriate capability index and comment.
- (iv) Using a technique, management has improved the operation 3 to a mean time of 8 hours. What proportion of the orders will now meet the goal?  
(Use Standard Normal Distribution table) 20
- (b) (i) Discuss the factors influencing the facility location selection. 10
- (ii) For expansion of a car manufacturing plant, three new locations are to be considered based on three factors:

Availability of labour, Proximity to the suppliers, and Proximity to the markets.

The weightage of these factors are given as 40%, 35%, and 25% respectively. The rating (on 100-point scale) of the locations against these factors are given in the following table:

Location	Availability of labour	Proximity to the suppliers	Proximity to the markets
X	70	60	45
Y	60	45	90
Z	55	95	50

Find the best and worst location for the new plant. 10

- (c) Spot welding of two steel sheets each of 1 mm thickness is performed using 20,000 A welding current supplied for 0.15 seconds. Assume that:
- (i) interface contact resistance is 200 micro-ohms,
- (ii) heat required for melting unit volume of steel is  $10 \text{ J/mm}^3$ , and
- (iii) only 60% of heat generated is used for melting of metal at the interface.
- Calculate: 10
- (I) Heat generated, J.
- (II) Volume of the weld nugget,  $\text{mm}^3$ .

- Q8.** (a) (i) Discuss the mechanism of material removal in ultrasonic machining. 10
- (ii) What are the different parameters affecting the material removal rate in ultrasonic machining? Show the variation of material removal rate with respect to these parameters using suitable schematic. 10
- (b) (i) Discuss the ABC, VED and SDE classification of inventory items. 10
- (ii) A plastic moulding company provides the following details of various products in terms of annual demand and unit cost.
- Classify the products in A, B and C categories. 10

Item Code #	Annual Demand	Cost/Unit (Rs.)
XA-101	400	4.00
XA-102	300	5.00
XA-103	120	3.00
XA-104	80	2.00
XA-105	50	2.50
XA-106	40	1.50
XA-107	20	2.20
XA-108	15	32.00

XA-109	8	51.80
XA-110	6	42.00
XA-111	5	3.00

- (c) Discuss the various steps used in sourcing of a product or service. Also, mention the name of the factors influencing the sourcing decision. 10



**MECHANICAL ENGINEERING Paper II****Time Allowed: Three Hours****Maximum Marks: 250****Question Paper Specific Instructions**

**Please read each of the following instructions carefully before attempting questions**

There are EIGHT questions divided in two Sections and printed both in HINDI and in ENGLISH.

Candidate has to attempt FIVE questions in all.

Question Nos. 1 and 5 are compulsory and out of the remaining, THREE are to be attempted choosing at least ONE question from each Section.

The number of marks carried by a question/part is indicated against it.

Answers must be written in the medium authorized in the Admission Certificate which must be stated clearly on the cover of this Question-cum-Answer (QCA) Booklet in the space provided. No marks will be given for answers written in a medium other than the authorized one.

Wherever any assumptions are made for answering a question, they must be clearly indicated. Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.

Unless otherwise mentioned, symbols and notations carry their usual standard meanings.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

**SECTION-A**

1. (a) Consider the system shown in Fig. 1(a). The two chambers initially have equal volumes of 28 litres and contain air ( $C_p = 1.005$  kJ/kg-K and  $C_v = 0.717$  kJ/kg-K) and hydrogen ( $C_p = 14.32$  kJ/kg-K and  $C_v = 10.17$  kJ/kg-K), respectively. The chambers are separated by a friction-less piston which is non-heat-conducting. Both the gases are initially at 140 kPa and 40°C. Heat is added to the air side until the pressure of both the gases reaches 280 kPa. All outside walls of the chambers are insulated except for the surface where heat is added to air. Calculate the final temperature of the air.

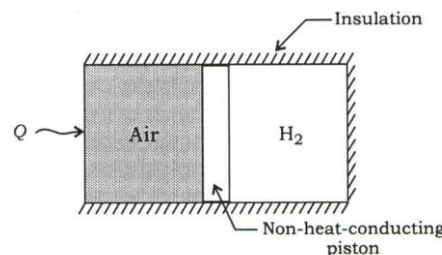


Fig. 1(a)

10

- (b) What is 'choked flow' in a convergent-divergent nozzle? Explain, with diagram, the effect of pressure ratio on exit velocity of compressible gas in a convergent-divergent nozzle. 10
- (c) An axial flow compressor with inlet and outlet angles of 40° and 15°, respectively has been designed for 50% reaction. The compressor has a pressure ratio of 6 : 1 and overall isentropic efficiency of 0.80, when inlet static temperature is 41°C. The blade speed and axial velocity are constant

- throughout. Assuming a value of 210 m/s for blade speed, find the number of stages required if the work done factor is 0.88 for all the stages. Take  $C_p = 1.005$  kJ/kg-K and  $\gamma = 1.4$  for air. 10
- (d) Hot water is flowing through a pipe made of cast iron having thermal conductivity of 52 W/m-°C, with an average velocity of 1.5 m/s. The inner and outer diameters of the pipe are 3 cm and 3.5 cm, respectively. The pipe passes through a 15 m long section of a basement whose temperature is 15°C. The temperature of the water drops from 70°C to 67°C as it passes through the basement. The heat transfer coefficient on the inner surface of the pipe is 400 W/m<sup>2</sup>-°C. Determine the combined convection and radiation heat transfer coefficient at the outer surface of the pipe. 10
- (e) (i) Define the total and spectral black body emissive powers. How are they related to each other? 5
- (ii) Consider two identical bodies, one at 1000 K and the other at 1500 K. Which body emits more radiation in the shorter wavelength region? Which body emits more radiation at a wavelength of 20  $\mu\text{m}$ ? 5
2. (a) 10 g of water at 20°C is converted into ice at -10°C at constant atmospheric pressure. Assuming the specific heat of liquid water to remain constant at 4.2 J/g-K and that of ice to be half of this value and taking the latent heat of fusion of ice at 0°C to be 335 J/g, calculate the total entropy change of the system. 20
- (b) A shaft having diameter of 5 cm rotates in a bearing made of cast iron. The shaft rotates at 4500 r.p.m. The bearing is 15 cm long, 8 cm outer diameter and has thermal conductivity of 70 W/m-K. There is a uniform clearance between the shaft and the bearing of 0.6 mm. The clearance is filled with a lubricating oil having thermal conductivity of 0.14 W/m-K and dynamic viscosity of 0.03 N-s/m<sup>2</sup>. The bearing is cooled externally by a liquid, and its outer surface is maintained at 40°C. Disregarding the heat conduction through the shaft and assuming only one-dimensional heat transfer, determine (i) the rate of heat transfer to the coolant, (ii) the surface temperature of the shaft and (iii) the mechanical power wasted by the viscous dissipation in the lubricating oil. 20
- (c) Air ( $C_p = 1.05$  kJ/kg-K,  $\gamma = 1.38$ ) at 3 bar pressure and  $T = 600$  K is flowing with a velocity of 180 m/s inside a 20 cm diameter duct. Calculate the—
- (i) mass flow rate;
- (ii) stagnation temperature;
- (iii) Mach number;
- (iv) stagnation pressure assuming flow to be (1) compressible and (2) incompressible. 10
3. (a) (i) How do the specific work output and efficiency vary with pressure ratio in a gas turbine?
- (ii) Prove that the efficiency of a gas turbine corresponding to the maximum work done in a Brayton cycle is given by the relation

$$\eta_{w_{\max}} = 1 - \frac{1}{\sqrt{t}},$$

where  $t$  is the ratio of the maximum and minimum temperatures. 20



- (b) A solar collector, as shown in Fig. 3(b) below, having dimensions as 1 m wide and 5 m long, has constant spacing of 3 cm between the glass cover and the collector plate. Air enters the collector at 30°C and at a rate of 0.15 m<sup>3</sup>/s through the 1 m wide edge and flows along the 5 m long passageway. If the average temperatures of the glass cover and the collector plate are 20°C and 60°C, respectively, determine (i) the net rate of heat transfer to the air in the collector and (ii) the temperature rise of air as it flows through the collector.

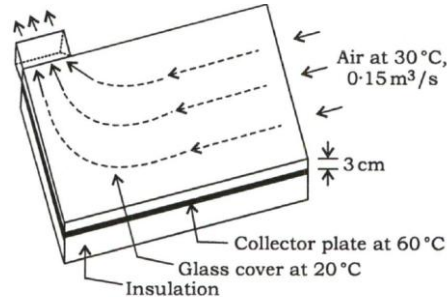


Fig. 3(b)

The properties of air at 1 atm and an estimated average temperature of 35°C may be taken as:

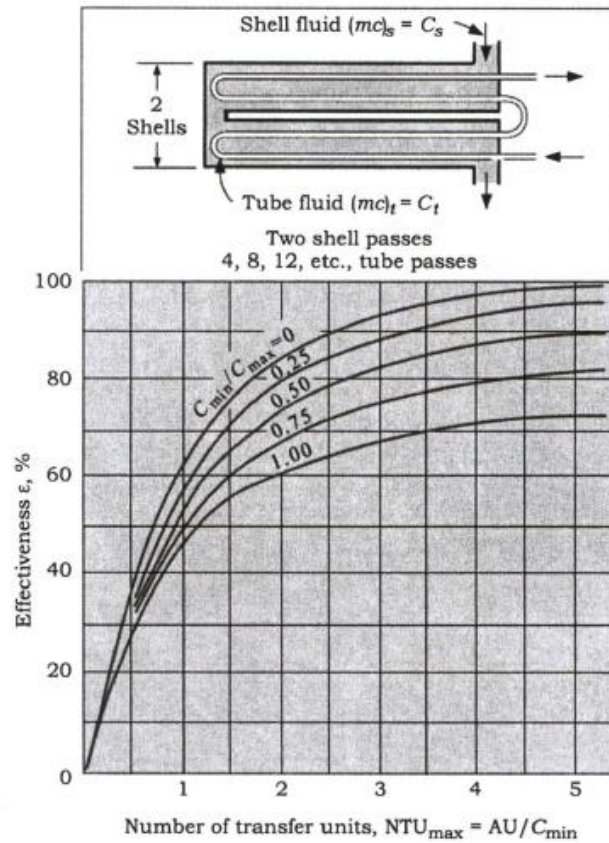
$$\rho = 1.145 \text{ kg/m}^3, k = 0.02625 \text{ W/m}\cdot\text{°C}, \nu = 1.655 \times 10^{-5} \text{ m}^2/\text{s},$$

$$C_p = 1.007 \text{ J/kg}\cdot\text{°C}, \text{Pr} = 0.7268 \quad 20$$

- (c) A windshield of a car, having dimensions as 0.6 m high and 1.8 m long, is electrically heated and is subjected to parallel winds at 1 atm, 0°C and 80 km/hr. The electrical power consumption is observed to be 50 W, when the exposed surface temperature of the windshield is 4°C. Disregarding the radiation and heat transfer from the inner surface and using the momentum heat transfer analogy, determine the drag force the wind exerts on the windshield. The properties of air at 0°C and 1 atm may be taken as:

$$\rho = 1.292 \text{ kg/m}^3, C_p = 1.006 \text{ kJ/kg}\cdot\text{K}, \text{Pr} = 0.7362 \quad 10$$

4. (a) A single-stage impulse turbine rotor has a mean blade ring diameter of 500 mm and rotates at a speed of 10000 r.p.m. The nozzle angle is 20° and the steam leaves the nozzles with a velocity of 900 m/s. The blades are equiangular and the blade friction factor is 0.85. Construct velocity diagrams for the blades and determine the inlet angle of the blades for shockless entry of steam. Also, determine (i) the diagram power for a steam flow of 750 kg/hr, (ii) the diagram efficiency, (iii) the axial thrust and (iv) the loss of kinetic energy due to friction. 20
- (b) (i) Explain the effect of impeller blade shape on the performance of a centrifugal compressor with the help of an exit velocity diagram and pressure ratio-mass flow rate curve.
- (ii) Discuss the phenomena of surging and choking in centrifugal compressors. 20
- (c) A shell and tube heat exchanger operates with two shell passes and four tube passes. The shell side fluid is ethylene glycol, which enters at 140°C and leaves at 80°C with a flow rate of 4500 kg/hr. Water flows in the tubes, entering at 35°C and leaving at 85°C. The overall heat transfer coefficient for this arrangement is 850 W/m<sup>2</sup>·°C. Calculate the flow rate of water required and the area of the heat exchanger. The specific heat of ethylene glycol may be taken as 2.742 J/g·°C and the specific heat of water may be taken as 4.175 J/g·°C. For NTU relations, the following figure may be used.



10

## SECTION-B

5. (a) Can alcohols be used as fuel in IC engine? Explain with advantages and disadvantages. 10
- (b) A water-filled reactor with a volume of  $1 \text{ m}^3$  is at 20 MPa and  $360^\circ\text{C}$ , and is placed inside a containment room as shown in Fig. 5(b). The room is well-insulated and initially evacuated. Due to a failure, the reactor ruptures and the water fills the containment room. Find the minimum room volume so that the final pressure does not exceed 200 kPa. [Use steam table data given at the end of the Paper]

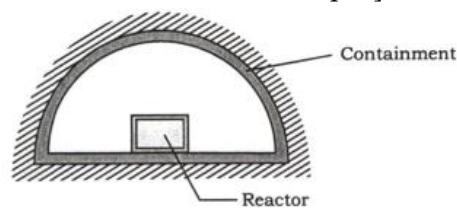


Fig. 5(b)

10

- (c) Using a schematic and  $T-s$  diagram, explain how with perfect regeneration for a simple steam power plant (Rankine) cycle, thermal efficiency can approach Carnot efficiency. 10
- (d) Discuss the effect of the following parameters on the performance of a vapor compression refrigeration system with the help of  $p-h$  diagram:
- Suction pressure.
  - Delivery pressure.
  - Subcooling of liquid.
  - Superheating of vapors. 10
- (e) The room air is recirculated at the rate of  $40 \text{ m}^3$  per minute and the outdoor air enters a cooling coil of an air conditioner at  $32^\circ\text{C}$  DBT and  $18^\circ\text{C}$  WBT. The

effective surface temperature of the coil is  $4.5^{\circ}\text{C}$ . The surface area of the coil is such as would give 12 kW of refrigeration with the given entering conditions of air. Determine the DBT and WBT of the air leaving the coil and the coil bypass factor.

[Psychrometric chart is given at the end of this Paper] 10

6. (a) A four-cylinder diesel engine with swept volume of 0.98 litre is tested on a performance bed. The engine running at a speed of 2500 r.p.m. against a brake with arm of 0.3 m produces brake load of 190 N with fuel consumption of 6.8 litres/hr. The calorific value of fuel is 45000 kJ/kg and specific gravity of fuel is 0.82. A Morse test is carried out on the engine by cutting off the fuel supply of individual cylinder in the order 1, 2, 3, 4 with corresponding brake loads 131 N, 135 N, 133 N and 137 N, respectively. Calculate the b.p., b.m.e.p., brake thermal efficiency, b.s.f.c, i.p., mechanical efficiency and i.m.e.p. of the engine at test speed. 20
- (b) A power plant operates on a regenerative steam cycle with one closed feedwater heater. Steam enters the first turbine stage at 125 bar,  $500^{\circ}\text{C}$  and expands to 10 bar, where some of the steam is extracted and diverted to the closed feedwater heater. Condensate exiting the feedwater heater as saturated liquid at 10 bar passes through a trap into the condenser. The feedwater exits the heater at 120 bar with a temperature of  $170^{\circ}\text{C}$ . The condenser pressure is 0.06 bar. Assuming isentropic turbine and pump work, determine the thermal efficiency of the cycle. At 125 bar,  $500^{\circ}\text{C}$  for steam,  $h = 3343.6$  kJ/kg and  $s = 6.4651$  kJ/kg-K. 20
- [Use steam tables provided at the end of this Paper]
- (c) Explain  $\text{NH}_3$ -water vapor absorption refrigeration system with a neat diagram. What are the desired properties of refrigerant-absorber combination? 10
7. (a) (i) Briefly discuss HC, CO and  $\text{NO}_x$  emission formation in SI engine. Explain the dependence of these emissions on equivalence ratio with a neat diagram. 10
- (ii) An IC engine working on an ideal Otto cycle has AFR of 15 : 1 and compression ratio of 9 : 1. The pressure and temperature at the start of compression are 1 bar and  $27^{\circ}\text{C}$ , respectively. Find the maximum temperature and pressure of the cycle. Assume that compression process follows the law  $pV^{1.33} = C$ , the calorific value of fuel is 43000 kJ/kg and  $C_v$  of working fluid is 0.717 kJ/kg-K. 10
- (b) A food processing room has a very high latent heat load and is required to be air conditioned as per the following data:
- Room design conditions :  $20^{\circ}\text{C}$  DBT, 60% RH  
 Outside conditions :  $45^{\circ}\text{C}$  DBT,  $30^{\circ}\text{C}$  WBT  
 Room sensible heat : 35 kW  
 Room latent heat : 20 kW  
 The ventilation air requirement is 90 cmm
- Determine the (i) ventilation load, (ii) room and effective sensible heat factors and (iii) ADP and amount of reheat for economical design. Assume bypass factor of the coil as 0.05.
- [Psychrometric chart is given at the end of this Paper] 20

Table for Properties of Air

$T$ (K)	$\rho$ (kg/m <sup>3</sup> )	$c_p$ (kJ/kg.K)	$\mu$ (kg/m.s $\times 10^5$ )	$\nu$ (m <sup>2</sup> /s $\times 10^6$ )	$k$ (W/m.K)	$\alpha$ (m <sup>2</sup> /s $\times 10^4$ )	Pr
100	3.9010	1.0266	0.6924	1.923	0.009246	0.02501	0.770
150	2.3675	1.0099	1.0283	4.343	0.013735	0.05745	0.753
200	1.7687	1.0061	1.3289	7.49	0.01809	0.10165	0.739
250	1.4128	1.0053	1.488	9.49	0.02227	0.13161	0.722
300	1.1774	1.0057	1.983	15.68	0.02624	0.2216	0.708
350	0.9980	1.0090	2.075	20.76	0.03003	0.2983	0.697
400	0.8826	1.0140	2.286	25.90	0.03365	0.3760	0.689
450	0.7833	1.0207	2.284	28.86	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	37.90	0.04038	0.5564	0.680
550	0.6423	1.0392	2.848	44.34	0.04360	0.6532	0.680
600	0.5879	1.0551	3.018	51.34	0.04649	0.7512	0.680
650	0.5430	1.0635	3.177	58.51	0.04953	0.8578	0.682
700	0.5030	1.0752	3.322	66.25	0.05230	0.9672	0.684
750	0.4709	1.0856	3.481	73.91	0.05509	1.0774	0.686
800	0.4405	1.0978	3.625	82.29	0.05779	1.1951	0.689
850	0.4149	1.1095	3.765	90.75	0.06028	1.3097	0.692
900	0.3925	1.1212	3.899	99.3	0.06269	1.4271	0.696
950	0.3716	1.1321	4.023	108.2	0.06525	1.5610	0.699
1000	0.3524	1.1417	4.152	117.8	0.06752	1.6779	0.702
1100	0.3204	1.160	4.44	136.6	0.0732	1.969	0.704
1200	0.2947	1.179	4.92	159.1	0.0782	2.251	0.707
1300	0.2707	1.197	4.93	182.1	0.0837	2.583	0.705
1400	0.2515	1.214	5.17	205.5	0.0891	2.920	0.705
1500	0.2355	1.230	5.40	229.1	0.0946	3.262	0.705
1600	0.2211	1.248	5.63	254.5	0.100	3.609	0.705

(c) Prove mathematically that for maximum discharge through a chimney of a certain height and cross-section, the absolute temperature of gases bears a certain ratio to the absolute temperature of the outside atmosphere, in case of natural draught of a boiler. 10

8. (a) A VCR cycle refrigerator driven by a 60 kW compressor has a COP of 6.0. The enthalpies of saturated liquid and saturated vapor refrigerant at condenser temperature of 35°C are 114.95 kJ/kg and 283.89 kJ/kg, respectively. The saturated refrigerant vapor leaving evaporator has an enthalpy of 275.76 kJ/kg. Find the temperature of refrigerant at the exit of compressor. The  $C_p$  of refrigerant is 0.62 kJ/kg-K. 20
- (b) In a combined gas turbine-steam turbine power plant, the exhaust gas from the open-cycle gas turbine is the supply gas to the steam generator of the steam cycle at which additional fuel is burnt in the gas. The pressure ratio for the gas turbine is 7.5, the air inlet temperature is 15°C and the maximum temperature is 750°C. Combustion of additional fuel raises the gas temperature to 750°C and the gas leaves the steam generator at 100°C. The steam is supplied to the steam turbine at 50 bar and 600°C and the condenser pressure is 0.1 bar. The total power output of the plant is 200 MW. The calorific value of the fuel burnt is 43.3 MJ/kg. Neglecting the effect of the mass flow rate of fuel on the air flow, determine (i) the flow rate of air and steam required, (ii) the power outputs of the gas turbine and steam turbine, (iii) the thermal efficiency of the combined plant and (iv) the air-fuel ratio.

Take  $C_p = 1.11$  kJ/kg-K and  $\gamma = 1.33$  for combustion gases; and  $C_p = 1.005$  kJ/kg-K and  $\gamma = 1.4$  for air. Neglect pump work. Condensate enthalpy at 0.1 bar = 192 kJ/kg. 20

- (c) Two vapor power cycles are coupled in series where heat lost by one is absorbed by the other completely. If  $\eta_1$  is the thermal efficiency of the topping cycle and  $\eta_2$  is the thermal efficiency of the bottom cycle, determine the efficiency of the combined cycle in terms of these efficiencies. Assume cycles to be reversible. 10



Saturated water—Temperature table

Temp., $T$ °C	Sat. press., $P_{\text{sat}}$ , kPa	Specific volume, $\text{m}^3/\text{kg}$		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
		Sat. liquid, $v_f$	Sat. vapor, $v_g$	Sat. liquid, $u_f$	Evap., $u_{fg}$	Sat. vapor, $u_g$	Sat. liquid, $h_f$	Evap., $h_{fg}$	Sat. vapor, $h_g$	Sat. liquid, $s_f$	Evap., $s_{fg}$	Sat. vapor, $s_g$
0.01	0.6117	0.001000	206.00	0.000	2374.9	2374.9	0.001	2500.9	2500.9	0.0000	9.1556	9.1556
5	0.8725	0.001000	147.03	21.019	2360.8	2381.8	21.020	2489.1	2510.1	0.0763	8.9487	9.0249
10	1.2281	0.001000	106.32	42.020	2346.6	2388.7	42.022	2477.2	2519.2	0.1511	8.7488	8.8999
15	1.7057	0.001001	77.885	62.980	2332.5	2395.5	62.982	2465.4	2528.3	0.2245	8.5559	8.7803
20	2.3392	0.001002	57.762	83.913	2318.4	2402.3	83.915	2453.5	2537.4	0.2965	8.3696	8.6661
25	3.1698	0.001003	43.340	104.83	2304.3	2409.1	104.83	2441.7	2546.5	0.3672	8.1895	8.5567
30	4.2469	0.001004	32.879	125.73	2290.2	2415.9	125.74	2429.8	2555.6	0.4368	8.0152	8.4520
35	5.6291	0.001006	25.205	146.63	2276.0	2422.7	146.64	2417.9	2564.6	0.5051	7.8466	8.3517
40	7.3851	0.001008	19.515	167.53	2261.9	2429.4	167.53	2406.0	2573.5	0.5724	7.6832	8.2556
45	9.5953	0.001010	15.251	188.43	2247.7	2436.1	188.44	2394.0	2582.4	0.6386	7.5247	8.1633
50	12.352	0.001012	12.026	209.33	2233.4	2442.7	209.34	2382.0	2591.3	0.7038	7.3710	8.0748
55	15.763	0.001015	9.5639	230.24	2219.1	2449.3	230.26	2369.8	2600.1	0.7680	7.2218	7.9898
60	19.947	0.001017	7.6670	251.16	2204.7	2455.9	251.18	2357.7	2608.8	0.8313	7.0769	7.9082
65	25.043	0.001020	6.1935	272.09	2190.3	2462.4	272.12	2345.4	2617.5	0.8937	6.9360	7.8296
70	31.202	0.001023	5.0396	293.04	2175.8	2468.9	293.07	2333.0	2626.1	0.9551	6.7989	7.7540
75	38.597	0.001026	4.1291	313.99	2161.3	2475.3	314.03	2320.6	2634.6	1.0158	6.6655	7.6812
80	47.416	0.001029	3.4053	334.97	2146.6	2481.6	335.02	2308.0	2643.0	1.0756	6.5355	7.6111
85	57.868	0.001032	2.8261	355.96	2131.9	2487.8	356.02	2295.3	2651.4	1.1346	6.4089	7.5435
90	70.183	0.001036	2.3593	376.97	2117.0	2494.0	377.04	2282.5	2659.6	1.1929	6.2853	7.4782
95	84.609	0.001040	1.9808	398.00	2102.0	2500.1	398.09	2269.6	2667.6	1.2504	6.1647	7.4151
100	101.42	0.001043	1.6720	419.06	2087.0	2506.0	419.17	2256.4	2675.6	1.3072	6.0470	7.3542
105	120.90	0.001047	1.4186	440.15	2071.8	2511.9	440.28	2243.1	2683.4	1.3634	5.9319	7.2952
110	143.38	0.001052	1.2094	461.27	2056.4	2517.7	461.42	2229.7	2691.1	1.4188	5.8193	7.2382
115	169.18	0.001056	1.0360	482.42	2040.9	2523.3	482.59	2216.0	2698.6	1.4737	5.7092	7.1829
120	198.67	0.001060	0.89133	503.60	2025.3	2528.9	503.81	2202.1	2706.0	1.5279	5.6013	7.1292
125	232.23	0.001065	0.77012	524.83	2009.5	2534.3	525.07	2188.1	2713.1	1.5816	5.4956	7.0771
130	270.28	0.001070	0.66808	546.10	1993.4	2539.5	546.38	2173.7	2720.1	1.6346	5.3919	7.0265
135	313.22	0.001075	0.58179	567.41	1977.3	2544.7	567.75	2159.1	2726.9	1.6872	5.2901	6.9773
140	361.53	0.001080	0.50850	588.77	1960.9	2549.6	589.16	2144.3	2733.5	1.7392	5.1901	6.9294
145	415.68	0.001085	0.44600	610.19	1944.2	2554.4	610.64	2129.2	2739.8	1.7908	5.0919	6.8827
150	476.16	0.001091	0.39248	631.66	1927.4	2559.1	632.18	2113.8	2745.9	1.8418	4.9953	6.8371
155	543.49	0.001096	0.34648	653.19	1910.3	2563.5	653.79	2098.0	2751.8	1.8924	4.9002	6.7927
160	618.23	0.001102	0.30680	674.79	1893.0	2567.8	675.47	2082.0	2757.5	1.9426	4.8066	6.7492
165	700.93	0.001108	0.27244	696.46	1875.4	2571.9	697.24	2065.6	2762.8	1.9923	4.7143	6.7067
170	792.18	0.001114	0.24260	718.20	1857.5	2575.7	719.08	2048.8	2767.9	2.0417	4.6233	6.6650
175	892.60	0.001121	0.21659	740.02	1839.4	2579.4	741.02	2031.7	2772.7	2.0906	4.5335	6.6242
180	1002.8	0.001127	0.19384	761.92	1820.9	2582.8	763.05	2014.2	2777.2	2.1392	4.4448	6.5841
185	1123.5	0.001134	0.17390	783.91	1802.1	2586.0	785.19	1996.2	2781.4	2.1875	4.3572	6.5447
190	1255.2	0.001141	0.15636	806.00	1783.0	2589.0	807.43	1977.9	2785.3	2.2355	4.2705	6.5059
195	1398.8	0.001149	0.14089	828.18	1763.6	2591.7	829.78	1959.0	2788.8	2.2831	4.1847	6.4678
200	1554.9	0.001157	0.12721	850.46	1743.7	2594.2	852.26	1939.8	2792.0	2.3305	4.0997	6.4302



Saturated water—Temperature table (Continued)

Temp., $T$ °C	Sat. press., $P_{\text{sat}}$ kPa	Specific volume, $\text{m}^3/\text{kg}$		Internal energy, $\text{kJ}/\text{kg}$			Enthalpy, $\text{kJ}/\text{kg}$			Entropy, $\text{kJ}/\text{kg}\cdot\text{K}$		
		Sat. liquid, $v_f$	Sat. vapor, $v_g$	Sat. liquid, $u_f$	Evap., $u_{fg}$	Sat. vapor, $u_g$	Sat. liquid, $h_f$	Evap., $h_{fg}$	Sat. vapor, $h_g$	Sat. liquid, $s_f$	Evap., $s_{fg}$	Sat. vapor, $s_g$
205	1724.3	0.001164	0.11508	872.86	1723.5	2596.4	874.87	1920.0	2794.8	2.3776	4.0154	6.3930
210	1907.7	0.001173	0.10429	895.38	1702.9	2598.3	897.61	1899.7	2797.3	2.4245	3.9318	6.3563
215	2105.9	0.001181	0.094680	918.02	1681.9	2599.9	920.50	1878.8	2799.3	2.4712	3.8489	6.3200
220	2319.6	0.001190	0.086094	940.79	1660.5	2601.3	943.55	1857.4	2801.0	2.5176	3.7664	6.2840
225	2549.7	0.001199	0.078405	963.70	1638.6	2602.3	966.76	1835.4	2802.2	2.5639	3.6844	6.2483
230	2797.1	0.001209	0.071505	986.76	1616.1	2602.9	990.14	1812.8	2802.9	2.6100	3.6028	6.2128
235	3062.6	0.001219	0.065300	1010.0	1593.2	2603.2	1013.7	1789.5	2803.2	2.6560	3.5216	6.1775
240	3347.0	0.001229	0.059707	1033.4	1569.8	2603.1	1037.5	1765.5	2803.0	2.7018	3.4405	6.1424
245	3651.2	0.001240	0.054656	1056.9	1545.7	2602.7	1061.5	1740.8	2802.2	2.7476	3.3596	6.1072
250	3976.2	0.001252	0.050085	1080.7	1521.1	2601.8	1085.7	1715.3	2801.0	2.7933	3.2788	6.0721
255	4322.9	0.001263	0.045941	1104.7	1495.8	2600.5	1110.1	1689.0	2799.1	2.8390	3.1979	6.0369
260	4692.3	0.001276	0.042175	1128.8	1469.9	2598.7	1134.8	1661.8	2796.6	2.8847	3.1169	6.0017
265	5085.3	0.001289	0.038748	1153.3	1443.2	2596.5	1159.8	1633.7	2793.5	2.9304	3.0358	5.9662
270	5503.0	0.001303	0.035622	1177.9	1415.7	2593.7	1185.1	1604.6	2789.7	2.9762	2.9542	5.9305
275	5946.4	0.001317	0.032767	1202.9	1387.4	2590.3	1210.7	1574.5	2785.2	3.0221	2.8723	5.8944
280	6416.6	0.001333	0.030153	1228.2	1358.2	2586.4	1236.7	1543.2	2779.9	3.0681	2.7898	5.8579
285	6914.6	0.001349	0.027756	1253.7	1328.1	2581.8	1263.1	1510.7	2773.7	3.1144	2.7066	5.8210
290	7441.8	0.001366	0.025554	1279.7	1296.9	2576.5	1289.8	1476.9	2766.7	3.1608	2.6225	5.7834
295	7999.0	0.001384	0.023528	1306.0	1264.5	2570.5	1317.1	1441.6	2758.7	3.2076	2.5374	5.7450
300	8587.9	0.001404	0.021659	1332.7	1230.9	2563.6	1344.8	1404.8	2749.6	3.2548	2.4511	5.7059
305	9209.4	0.001425	0.019932	1360.0	1195.9	2555.8	1373.1	1366.3	2739.4	3.3024	2.3633	5.6657
310	9865.0	0.001447	0.018333	1387.7	1159.3	2547.1	1402.0	1325.9	2727.9	3.3506	2.2737	5.6243
315	10,556	0.001472	0.016849	1416.1	1121.1	2537.2	1431.6	1283.4	2715.0	3.3994	2.1821	5.5816
320	11,284	0.001499	0.015470	1445.1	1080.9	2526.0	1462.0	1238.5	2700.6	3.4491	2.0881	5.5372
325	12,051	0.001528	0.014183	1475.0	1038.5	2513.4	1493.4	1191.0	2684.3	3.4998	1.9911	5.4908
330	12,858	0.001560	0.012979	1505.7	993.5	2499.2	1525.8	1140.3	2666.0	3.5516	1.8906	5.4422
335	13,707	0.001597	0.011848	1537.5	945.5	2483.0	1559.4	1086.0	2645.4	3.6050	1.7857	5.3907
340	14,601	0.001638	0.010783	1570.7	893.8	2464.5	1594.6	1027.4	2622.0	3.6602	1.6756	5.3358
345	15,541	0.001685	0.009772	1605.5	837.7	2443.2	1631.7	963.4	2595.1	3.7179	1.5585	5.2765
350	16,529	0.001741	0.008806	1642.4	775.9	2418.3	1671.2	892.7	2563.9	3.7788	1.4326	5.2114
355	17,570	0.001808	0.007872	1682.2	706.4	2388.6	1714.0	812.9	2526.9	3.8442	1.2942	5.1384
360	18,666	0.001895	0.006950	1726.2	625.7	2351.9	1761.5	720.1	2481.6	3.9165	1.1373	5.0537
365	19,822	0.002015	0.006009	1777.2	526.4	2303.6	1817.2	605.5	2422.7	4.0004	0.9489	4.9493
370	21,044	0.002217	0.004953	1844.5	385.6	2230.1	1891.2	443.1	2334.3	4.1119	0.6890	4.8009
373.95	22,064	0.003106	0.003106	2015.7	0	2015.7	2084.3	0	2084.3	4.4070	0	4.4070

Saturated water—Pressure table

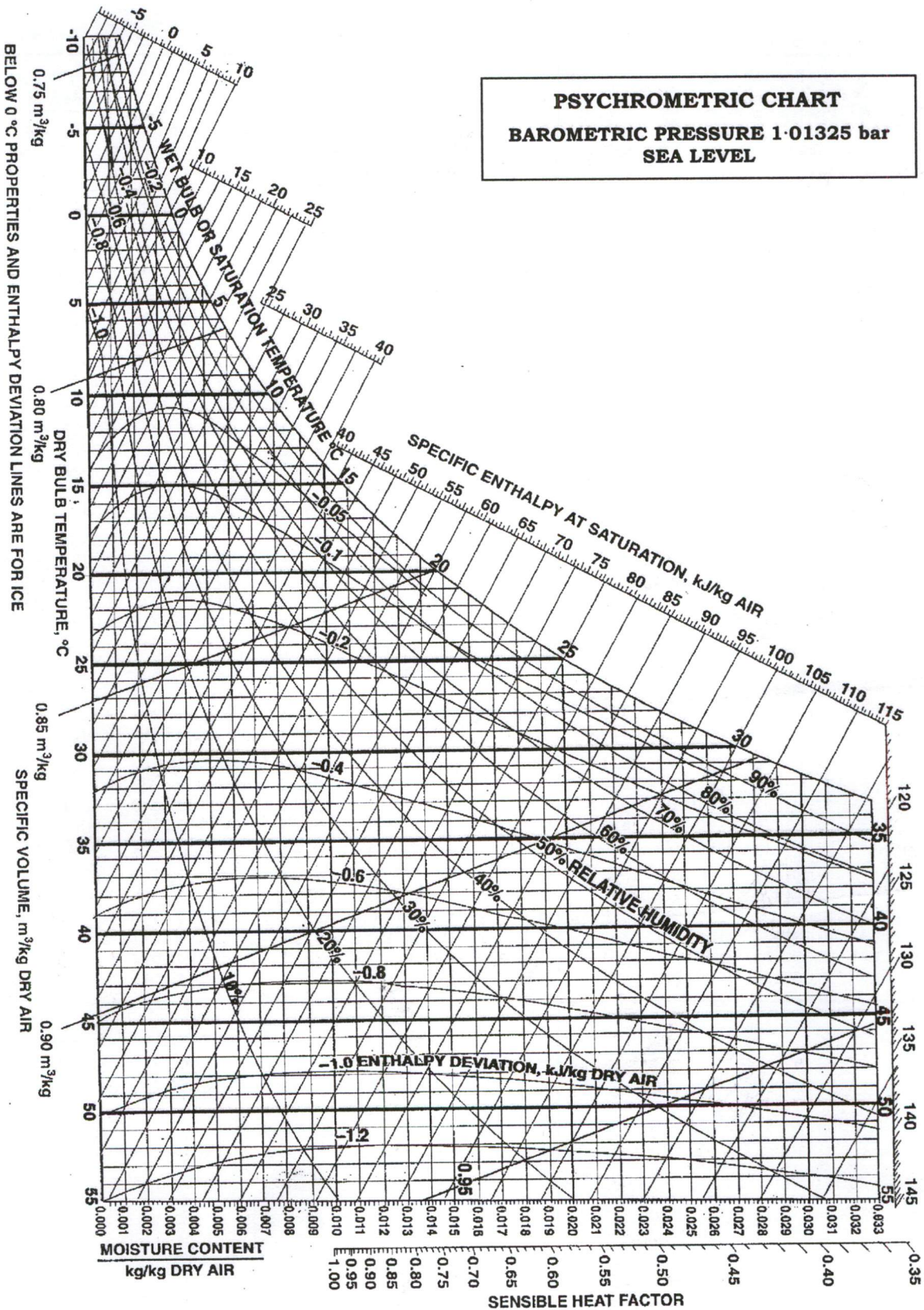
Press., <i>P</i> , kPa	Sat. temp., <i>T</i> <sub>sat</sub> , °C	Specific volume, m <sup>3</sup> /kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
		Sat. liquid, <i>v</i> <sub>f</sub>	Sat. vapor, <i>v</i> <sub>g</sub>	Sat. liquid, <i>u</i> <sub>f</sub>	Evap., <i>u</i> <sub>fg</sub>	Sat. vapor, <i>u</i> <sub>g</sub>	Sat. liquid, <i>h</i> <sub>f</sub>	Evap., <i>h</i> <sub>fg</sub>	Sat. vapor, <i>h</i> <sub>g</sub>	Sat. liquid, <i>s</i> <sub>f</sub>	Evap., <i>s</i> <sub>fg</sub>	Sat. vapor, <i>s</i> <sub>g</sub>
1.0	6.97	0.001000	129.19	29.302	2355.2	2384.5	29.303	2484.4	2513.7	0.1059	8.8690	8.9749
1.5	13.02	0.001001	87.964	54.686	2338.1	2392.8	54.688	2470.1	2524.7	0.1956	8.6314	8.8270
2.0	17.50	0.001001	66.990	73.431	2325.5	2398.9	73.433	2459.5	2532.9	0.2606	8.4621	8.7227
2.5	21.08	0.001002	54.242	88.422	2315.4	2403.8	88.424	2451.0	2539.4	0.3118	8.3302	8.6421
3.0	24.08	0.001003	45.654	100.98	2306.9	2407.9	100.98	2443.9	2544.8	0.3543	8.2222	8.5765
4.0	28.96	0.001004	34.791	121.39	2293.1	2414.5	121.39	2432.3	2553.7	0.4224	8.0510	8.4734
5.0	32.87	0.001005	28.185	137.75	2282.1	2419.8	137.75	2423.0	2560.7	0.4762	7.9176	8.3938
7.5	40.29	0.001008	19.233	168.74	2261.1	2429.8	168.75	2405.3	2574.0	0.5763	7.6738	8.2501
10	45.81	0.001010	14.670	191.79	2245.4	2437.2	191.81	2392.1	2583.9	0.6492	7.4996	8.1488
15	53.97	0.001014	10.020	225.93	2222.1	2448.0	225.94	2372.3	2598.3	0.7549	7.2522	8.0071
20	60.06	0.001017	7.6481	251.40	2204.6	2456.0	251.42	2357.5	2608.9	0.8320	7.0752	7.9073
25	64.96	0.001020	6.2034	271.93	2190.4	2462.4	271.96	2345.5	2617.5	0.8932	6.9370	7.8302
30	69.09	0.001022	5.2287	289.24	2178.5	2467.7	289.27	2335.3	2624.6	0.9441	6.8234	7.7675
40	75.86	0.001026	3.9933	317.58	2158.8	2476.3	317.62	2318.4	2636.1	1.0261	6.6430	7.6691
50	81.32	0.001030	3.2403	340.49	2142.7	2483.2	340.54	2304.7	2645.2	1.0912	6.5019	7.5931
75	91.76	0.001037	2.2172	384.36	2111.8	2496.1	384.44	2278.0	2662.4	1.2132	6.2426	7.4558
100	99.61	0.001043	1.6941	417.40	2088.2	2505.6	417.51	2257.5	2675.0	1.3028	6.0562	7.3589
101.325	99.97	0.001043	1.6734	418.95	2087.0	2506.0	419.06	2256.5	2675.6	1.3069	6.0476	7.3545
125	105.97	0.001048	1.3750	444.23	2068.8	2513.0	444.36	2240.6	2684.9	1.3741	5.9100	7.2841
150	111.35	0.001053	1.1594	466.97	2052.3	2519.2	467.13	2226.0	2693.1	1.4337	5.7894	7.2231
175	116.04	0.001057	1.0037	486.82	2037.7	2524.5	487.01	2213.1	2700.2	1.4850	5.6865	7.1716
200	120.21	0.001061	0.88578	504.50	2024.6	2529.1	504.71	2201.6	2706.3	1.5302	5.5968	7.1270
225	123.97	0.001064	0.79329	520.47	2012.7	2533.2	520.71	2191.0	2711.7	1.5706	5.5171	7.0877
250	127.41	0.001067	0.71873	535.08	2001.8	2536.8	535.35	2181.2	2716.5	1.6072	5.4453	7.0525
275	130.58	0.001070	0.65732	548.57	1991.6	2540.1	548.86	2172.0	2720.9	1.6408	5.3800	7.0207
300	133.52	0.001073	0.60582	561.11	1982.1	2543.2	561.43	2163.5	2724.9	1.6717	5.3200	6.9917
325	136.27	0.001076	0.56199	572.84	1973.1	2545.9	573.19	2155.4	2728.6	1.7005	5.2645	6.9650
350	138.86	0.001079	0.52422	583.89	1964.6	2548.5	584.26	2147.7	2732.0	1.7274	5.2128	6.9402
375	141.30	0.001081	0.49133	594.32	1956.6	2550.9	594.73	2140.4	2735.1	1.7526	5.1645	6.9171
400	143.61	0.001084	0.46242	604.22	1948.9	2553.1	604.66	2133.4	2738.1	1.7765	5.1191	6.8955
450	147.90	0.001088	0.41392	622.65	1934.5	2557.1	623.14	2120.3	2743.4	1.8205	5.0356	6.8561
500	151.83	0.001093	0.37483	639.54	1921.2	2560.7	640.09	2108.0	2748.1	1.8604	4.9603	6.8207
550	155.46	0.001097	0.34261	655.16	1908.8	2563.9	655.77	2096.6	2752.4	1.8970	4.8916	6.7886
600	158.83	0.001101	0.31560	669.72	1897.1	2566.8	670.38	2085.8	2756.2	1.9308	4.8285	6.7593
650	161.98	0.001104	0.29260	683.37	1886.1	2569.4	684.08	2075.5	2759.6	1.9623	4.7699	6.7322
700	164.95	0.001108	0.27278	696.23	1875.6	2571.8	697.00	2065.8	2762.8	1.9918	4.7153	6.7071
750	167.75	0.001111	0.25552	708.40	1865.6	2574.0	709.24	2056.4	2765.7	2.0195	4.6642	6.6837



Saturated water—Pressure table (Continued)

Press., <i>P</i> , kPa	Sat. temp., <i>T</i> <sub>sat</sub> , °C	Specific volume, m <sup>3</sup> /kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
		Sat. liquid, <i>v</i> <sub>f</sub>	Sat. vapor, <i>v</i> <sub>g</sub>	Sat. liquid, <i>u</i> <sub>f</sub>	Evap., <i>u</i> <sub>fg</sub>	Sat. vapor, <i>u</i> <sub>g</sub>	Sat. liquid, <i>h</i> <sub>f</sub>	Evap., <i>h</i> <sub>fg</sub>	Sat. vapor, <i>h</i> <sub>g</sub>	Sat. liquid, <i>s</i> <sub>f</sub>	Evap., <i>s</i> <sub>fg</sub>	Sat. vapor, <i>s</i> <sub>g</sub>
800	170.41	0.001115	0.24035	719.97	1856.1	2576.0	720.87	2047.5	2768.3	2.0457	4.6160	6.6616
850	172.94	0.001118	0.22690	731.00	1846.9	2577.9	731.95	2038.8	2770.8	2.0705	4.5705	6.6409
900	175.35	0.001121	0.21489	741.55	1838.1	2579.6	742.56	2030.5	2773.0	2.0941	4.5273	6.6213
950	177.66	0.001124	0.20411	751.67	1829.6	2581.3	752.74	2022.4	2775.2	2.1166	4.4862	6.6027
1000	179.88	0.001127	0.19436	761.39	1821.4	2582.8	762.51	2014.6	2777.1	2.1381	4.4470	6.5850
1100	184.06	0.001133	0.17745	779.78	1805.7	2585.5	781.03	1999.6	2780.7	2.1785	4.3735	6.5520
1200	187.96	0.001138	0.16326	796.96	1790.9	2587.8	798.33	1985.4	2783.8	2.2159	4.3058	6.5217
1300	191.60	0.001144	0.15119	813.10	1776.8	2589.9	814.59	1971.9	2786.5	2.2508	4.2428	6.4936
1400	195.04	0.001149	0.14078	828.35	1763.4	2591.8	829.96	1958.9	2788.9	2.2835	4.1840	6.4675
1500	198.29	0.001154	0.13171	842.82	1750.6	2593.4	844.55	1946.4	2791.0	2.3143	4.1287	6.4430
1750	205.72	0.001166	0.11344	876.12	1720.6	2596.7	878.16	1917.1	2795.2	2.3844	4.0033	6.3877
2000	212.38	0.001177	0.099587	906.12	1693.0	2599.1	908.47	1889.8	2798.3	2.4467	3.8923	6.3390
2250	218.41	0.001187	0.088717	933.54	1667.3	2600.9	936.21	1864.3	2800.5	2.5029	3.7926	6.2954
2500	223.95	0.001197	0.079952	958.87	1643.2	2602.1	961.87	1840.1	2801.9	2.5542	3.7016	6.2558
3000	233.85	0.001217	0.066667	1004.6	1598.5	2603.2	1008.3	1794.9	2803.2	2.6454	3.5402	6.1856
3500	242.56	0.001235	0.057061	1045.4	1557.6	2603.0	1049.7	1753.0	2802.7	2.7253	3.3991	6.1244
4000	250.35	0.001252	0.049779	1082.4	1519.3	2601.7	1087.4	1713.5	2800.8	2.7966	3.2731	6.0696
5000	263.94	0.001286	0.039448	1148.1	1448.9	2597.0	1154.5	1639.7	2794.2	2.9207	3.0530	5.9737
6000	275.59	0.001319	0.032449	1205.8	1384.1	2589.9	1213.8	1570.9	2784.6	3.0275	2.8627	5.8902
7000	285.83	0.001352	0.027378	1258.0	1323.0	2581.0	1267.5	1505.2	2772.6	3.1220	2.6927	5.8148
8000	295.01	0.001384	0.023525	1306.0	1264.5	2570.5	1317.1	1441.6	2758.7	3.2077	2.5373	5.7450
9000	303.35	0.001418	0.020489	1350.9	1207.6	2558.5	1363.7	1379.3	2742.9	3.2866	2.3925	5.6791
10,000	311.00	0.001452	0.018028	1393.3	1151.8	2545.2	1407.8	1317.6	2725.5	3.3603	2.2556	5.6159
11,000	318.08	0.001488	0.015988	1433.9	1096.6	2530.4	1450.2	1256.1	2706.3	3.4299	2.1245	5.5544
12,000	324.68	0.001526	0.014264	1473.0	1041.3	2514.3	1491.3	1194.1	2685.4	3.4964	1.9975	5.4939
13,000	330.85	0.001566	0.012781	1511.0	985.5	2496.6	1531.4	1131.3	2662.7	3.5606	1.8730	5.4336
14,000	336.67	0.001610	0.011487	1548.4	928.7	2477.1	1571.0	1067.0	2637.9	3.6232	1.7497	5.3728
15,000	342.16	0.001657	0.010341	1585.5	870.3	2455.7	1610.3	1000.5	2610.8	3.6848	1.6261	5.3108
16,000	347.36	0.001710	0.009312	1622.6	809.4	2432.0	1649.9	931.1	2581.0	3.7461	1.5005	5.2466
17,000	352.29	0.001770	0.008374	1660.2	745.1	2405.4	1690.3	857.4	2547.7	3.8082	1.3709	5.1791
18,000	356.99	0.001840	0.007504	1699.1	675.9	2375.0	1732.2	777.8	2510.0	3.8720	1.2343	5.1064
19,000	361.47	0.001926	0.006677	1740.3	598.9	2339.2	1776.8	689.2	2466.0	3.9396	1.0860	5.0256
20,000	365.75	0.002038	0.005862	1785.8	509.0	2294.8	1826.6	585.5	2412.1	4.0146	0.9164	4.9310
21,000	369.83	0.002207	0.004994	1841.6	391.9	2233.5	1888.0	450.4	2338.4	4.1071	0.7005	4.8076
22,000	373.71	0.002703	0.003644	1951.7	140.8	2092.4	2011.1	161.5	2172.6	4.2942	0.2496	4.5439
22,064	373.95	0.003106	0.003106	2015.7	0	2015.7	2084.3	0	2084.3	4.4070	0	4.4070

**PSYCHROMETRIC CHART**  
**BAROMETRIC PRESSURE 1.01325 bar**  
**SEA LEVEL**



BELOW 0 °C PROPERTIES AND ENTHALPY DEVIATION LINES ARE FOR ICE

Ref. Point for SHF is 25 °C, 50% RH