भारतीय वन सेवा परीक्षा 2011
Indian Forest Services Examination

Sl. No. 171 **D–VSF–L–ZRB**

MECHANICAL ENGINEERING

Paper—II

Time Allowed : Three Hours	Maximum Marks : 200

INSTRUCTIONS

Candidates should attempt Question Nos. 1 and 5 which are compulsory, and any THREE of the remaining questions, selecting at least ONE question from each Section.

All questions carry equal marks.

Marks allotted to parts of a question are indicated against each.

Answers must be written in ENGLISH only.

If any data is considered insufficient, assume suitable value and indicate the same clearly.

Newton may be converted to kgf using the equality 1 kilonewton (1 kN) = 100 kgf, if found necessary.

All answers should be in SI units.

Take : 1 kcal = 4·187 kJ and 1 kg/cm^2 = 0·98 bar
1 bar = 10^5 pascals.

Universal gas constant = 8314·6 J/kmol-K.

Neat sketches may be drawn, wherever required.

The attached psychrometric chart is to be used for answering Question No. 6(b). Then the psychrometric chart may be detached from the question paper and attached firmly to your answer book.

Section—A

1. Answer any *four* parts :

(a) An imaginary engine receives heat and does work on a slowly moving piston at such rates that the cycle of operation of 1 kg of working fluid can be represented as a circle 10 cm in diameter on a p-v diagram on which 1 cm = 300 kPa and $1\ \text{cm} = 0 \cdot 1\ \text{m}^3/\text{kg}$.

(i) Determine how much work is done by each kg of working fluid for each cycle of operation.

(ii) If the heat rejected by the engine in a cycle is 1000 kJ per kg of working fluid, find the thermal efficiency of the engine. 10

(b) Explain the principle of carburetion. Develop an expression for air-fuel ratio for a simple carburetor taking compressibility into account. 10

(c) Explain the various mechanisms of lubrication bringing out their functions. What are the various desirable properties of lubricants? Explain how additives help to achieve these. 10

(d) If a fin is thin and long and tip losses are negligible, show that the heat transfer from the fin is given by

$$Q_0 = mkA\theta_0 \tanh ml$$

where $m = (hP/kA)^{\frac{1}{2}}$. 10

(e) For a balanced heat exchanger ($R = 1$), show that for counterflow arrangement

$$\varepsilon = \frac{NTU}{NTU + 1}$$ 10

2. (a) An ideal gas cycle consists of three reversible processes in the following sequence—(i) constant volume pressure rise, (ii) isentropic expansion to r times the initial volume and (iii) constant pressure decrease in volume. Sketch the cycle on the p-v and T-s diagrams. Show that the efficiency of the cycle is

$$\eta_{\text{cycle}} = \frac{r^{\gamma} - 1 - \gamma(r-1)}{r^{\gamma} - 1}$$

Evaluate the cycle efficiency, when $\gamma = \frac{4}{3}$ and $r = 8$. 15

(b) The following expressions for the equations of state and the specific heat C_p are obeyed by a certain gas :

$$v = \frac{RT}{p} + \alpha T^2 \text{ and } C_p = A + BT + C \cdot p$$

where α, A, B, C are constants. Obtain an expression for (i) the Joule-Thomson coefficient and (ii) the specific heat C_v. 15

(c) Show that the efficiency of a reversible engine is independent of the nature or amount of the working substance going through the cycle. 10

3. *(a)* A petrol engine with a compression ratio of 7 uses a mixture of isooctane and hexane as fuel. The pressure and temperature at the beginning of the compression process are 1 bar and 55·22 °C respectively. If the fuel-air mixture is 19·05% rich and the maximum pressure developed is 115·26 bar, evaluate the composition of the mixture (in percentage weight). Take, $C_v = 0{\cdot}717$ kJ/kg-K, $(CV)_{hexane} = 43$ MJ/kg, $(CV)_{isooctane} =$ 42 MJ/kg and $PV^{1{\cdot}31}$ is constant for the expansion and compression processes. 20

(b) *(i)* Explain the stages of combustion in SI and CI engines.

(ii) Discuss the phenomenon of knock in SI and CI engines.

(iii) Discuss the important qualities of SI and CI engine fuels. How are these fuels rated? 7+7+6=20

4. *(a)* What do you mean by radiation shield? Where is it used?

Two parallel discs of 1 m diameter are situated 2 m apart in the surroundings at a temperature of 20 °C. One side of a disc has an emissivity of 0·5 and is maintained at 500 °C by electrical resistance heating and the other side is insulated. The other disc is open to radiation on both sides. Determine the equilibrium temperature of the second disc and the heat flow rate from the first disc. Take, $F_{12} = 0{\cdot}06$ (for discs). Discuss the effect on the solution if both sides of the second disc are perfect mirrors. 3+17=20

(b) (i) Show that for laminar flow of air (Pr = 0·714), the local and average values of Nusselt number for natural convection heat transfer from or to a vertical plate are given by $\mathrm{Nu}_x = 0 \cdot 378\,\mathrm{Gr}^{1/4}$ or $\overline{\mathrm{Nu}}_L = 0 \cdot 504\,\mathrm{Gr}_L^{1/4}$.

(ii) A 15 cm outer diameter steel pipe lies 2 m vertically and 8 m horizontally in a large room with an ambient temperature of 30 °C. If the pipe surface is at 250 °C and the emissivity of the steel is 0·60, calculate the total rate of heat loss from the pipe to the atmosphere. Properties of air at 140 °C are $\rho = 0 \cdot 854\,\mathrm{kg/m^3}$, $C_p = 1 \cdot 01$ kJ/kg-K, $k = 0{\cdot}035$ W/m-K, Pr = 0·684 and $\nu = 27 \cdot 8 \times 10^{-6}\,\mathrm{m^2/s}$. For vertical part, use the formula

$$\mathrm{Nu} = 0 \cdot 13\,(\mathrm{Gr\,Pr})^{1/3}$$

and for horizontal part

$$\mathrm{Nu} = 0 \cdot 53\,(\mathrm{Gr}_d\,\mathrm{Pr})^{1/4}$$

15+5=20

Section—B

5. Answer any *four* parts :

(a) With the help of a schematic diagram, describe the working of a 'Benson boiler'. What are its advantages? 10

(b) How can the solar energy be used to obtain refrigeration effect? Explain with a neat and clear sketch. 10

(c) Differentiate between air-conditioning and air cooling. Whether household air-conditioners are properly named? Justify your answer. Show how air washer can be used for year-round air-conditioning. 10

(d) Prove that in a multistage turbine

$$\eta_t = \eta_s \times \mathrm{RF}$$

where η_t = overall turbine efficiency, η_s = small-stage efficiency and RF = reheat factor. 10

(e) What is the pressure coefficient of a centrifugal compressor? Derive

$$\psi_p = 1 - \phi_2 \cos\beta_2$$

where ϕ_2 = flow coefficient. 10

6. *(a)* *(i)* Which of the two factors (increase in the upper pressure limit and decrease in the lower pressure limit) has more adverse effect on COP of a refrigeration cycle?

(ii) Show the variation of capacity factor with varying evaporator temperature in the vapour-compression system of refrigeration, the condenser pressure remaining the same.

(iii) Show the actual vapour-compression cycle on a *p-h* diagram and explain the various irreversibilities with the help of *T-s* diagram.

(iv) What is the difference between multistage refrigeration and cascade refrigeration? 4+4+8+4=20

(b) (i) Define Effective Sensible Heat Factor (ESHF). How can ADP be determined with its help?

The following data refer to a public hall :

Total sensible heat = 10^5 kJ/h
Total latent heat = 60000 kJ/h
The room design condition $T_{db} = 27$ °C and $\phi = 60\%$.

The temperature rise of air (i.e., difference between the room design condition and supply air to the room) is 8 °C.

Find the SHF, show the process on the psychrometric chart and also calculate the volume of air supplied to room using approximate expression based on sensible heat and enthalpy drop.

(ii) To cut cooling loads to minimize the size of the air-conditioning plant, the energy conservation measures can help a lot. List such measures and discuss each in brief. Draw the schematic arrangement of a year-round air-conditioning system and explain its working with the help of psychrometric chart. 10+10=20

7. *(a)* What is a Fanno line and a Rayleigh line? Why do the end states of a normal shock lie on the Fanno line and Rayleigh line? Show these lines on a h-s diagram for various conditions. Give the physical meaning of this. 10

(b) A nozzle is designed assuming isentropic flow with an exit Mach number of 2·6. Air flows through it with a stagnation pressure and temperature of 2 MPa and 150 °C respectively. The mass flow rate is 5 kg/sec.

(i) Determine the exit pressure, temperature, area and throat area.

(ii) If back pressure at the nozzle exit is raised to 1·35 MPa, and the flow remains isentropic except for a normal shock wave, determine the exit Mach number and temperature, and the mass flow rate through the nozzle. Assume for the value of P / P_0 of 0·675, $M = 0{\cdot}85$ and $T / T_0 = 0{\cdot}845$ for isentropic flow. 15

(c) A centrifugal compressor with $20\,m^3$ of air per second at 1 bar and 15 °C is to be compressed through a pressure ratio of 1·5. The compression follows the law $pv^{1\cdot5}$ = constant. The velocity of flow at inlet and outlet remains constant and is equal to 60 m/s. The inlet and outlet impeller diameters are 0·6 m and 1·2 m respectively, and the speed of rotation is 5000 r.p.m.

(i) Find the blade angles at inlet and outlet of the impeller, and the angle at which the air from the impeller enters the casing.

(ii) Find the breadth of impeller blade at inlet and outlet.

It may be assumed that diffuser is not fitted and the whole pressure increase occurs in the impeller and that the blades have negligible thickness.

(iii) Sketch the velocity triangles at inlet and outlet of the impeller. 15

8. (a) Draw a neat sketch of a Heavy Water-cooled Reactor (HWR) or CANDU-type reactor power plant. Clearly show the various components. What are the advantages and disadvantages of this type of nuclear reactor over others? 10

(b) The yearly duration curve of a certain power plant can be considered a straight line from 30 MW to 10 MW. To meet this load, three turbine generator units, two rated at 15 MW each and one at 7·5 MW, are installed. Evaluate—

(i) installed capacity;

(ii) plant factor;

(iii) maximum demand;

(iv) load factor;

(v) utilization factor. 15

(c) A turbine model of 1 : 10 develops 1·84 kW under a head of 5 m of water at 480 r.p.m. Find the power developed by the prototype under a head of 40 m. Also find the speed of the prototype. Assume efficiency of both the turbines to be same. Find and verify the specific speeds. 15

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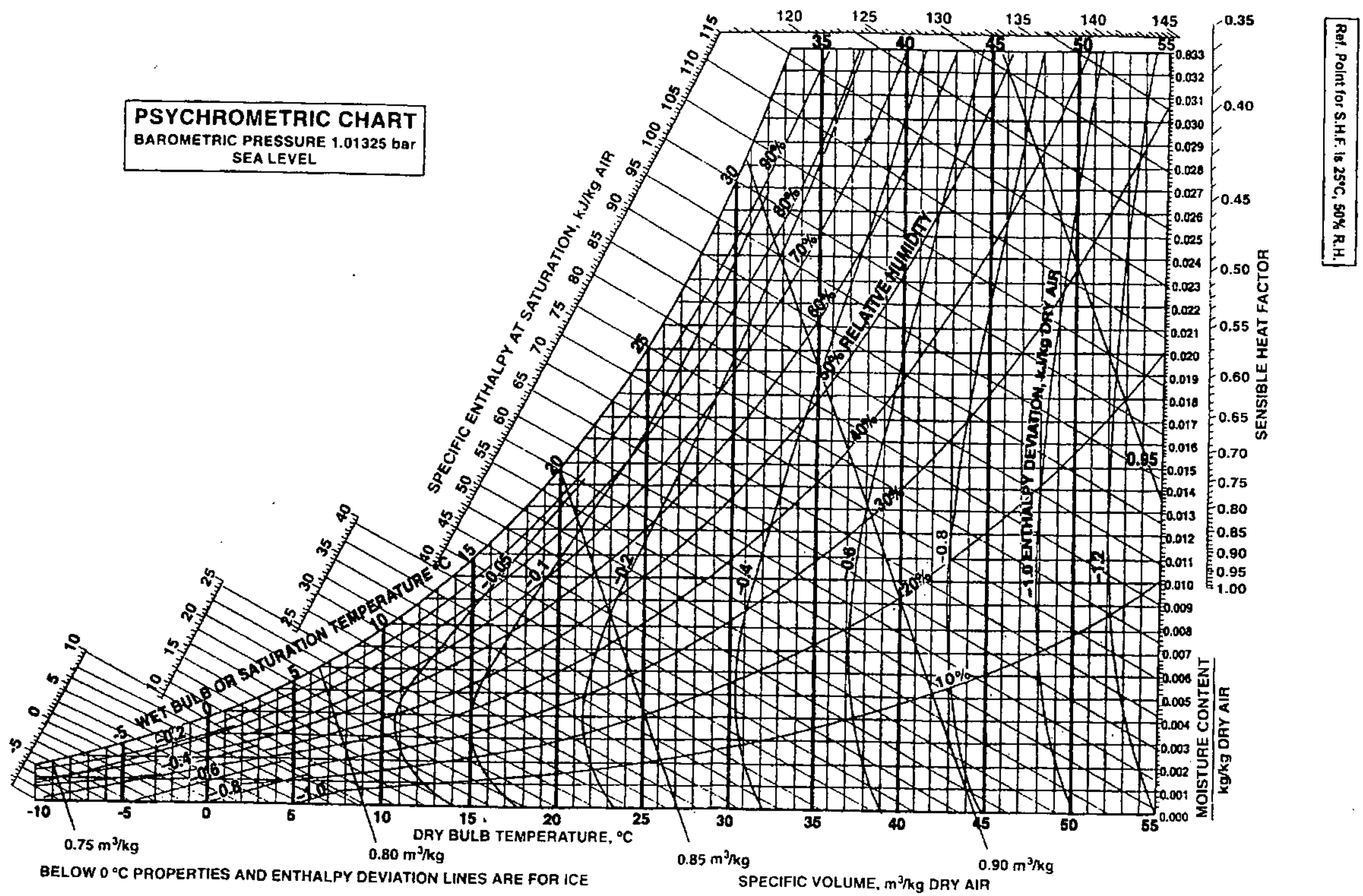
[For Q. No. 6(b)]


PSYCHROMETRIC CHART
BAROMETRIC PRESSURE 1.01325 bar
SEA LEVEL
Ref. Point for S.H.F. is 25°C, 50% R.H.
SPECIFIC ENTHALPY AT SATURATION, kJ/kg AIR
WET BULB OR SATURATION TEMPERATURE °C
RELATIVE HUMIDITY
ENTHALPY DEVIATION, kJ/kg DRY AIR
SENSIBLE HEAT FACTOR
MOISTURE CONTENT kg/kg DRY AIR
DRY BULB TEMPERATURE, °C
SPECIFIC VOLUME, m³/kg DRY AIR
0.75 m³/kg
0.80 m³/kg
0.85 m³/kg
0.90 m³/kg
BELOW 0 °C PROPERTIES AND ENTHALPY DEVIATION LINES ARE FOR ICE