MECHANICAL ENGINEERING

PAPER—I

Time Allowed : Three Hours

Maximum Marks : 300

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are EIGHT questions divided in two Sections.

Candidate has to attempt FIVE questions in all.

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

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

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 have their usual standard meanings.

Psychrometric Chart is given in Page No. 8.

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 QCA Booklet must be clearly struck off.

Answers must be written in ENGLISH only.

SECTION—A

1. *(a)* Discuss the sources of minor losses which can take place in circular pipes. 12

(b) Calculate the decrease in available energy when 25 kg of water at 95 °C mixed with 35 kg of water at 35 °C, the pressure being taken as constant and the temperature of the surroundings being 15 °C.

(Specific heat of water = 4·2 kJ/kg K) 12

(c) Draw a typical boiling curve for pool boiling of water at saturation temperature and atmospheric pressure, and mark each boiling regime. 12

(d) A diesel engine is working with a compression ratio of 18 : 1 and expansion ratio of 12 : 1. Calculate the air-standard cycle efficiency. Assume $\gamma = 1{\cdot}4$. If the relative efficiency of the engine is 50% and calorific value of diesel fuel is 45000 kJ/kg, find out the specific fuel consumption of the engine in kg/kWh. If this engine has its application for DG set purpose of 500 kW rating at full-load condition and is expected to operate for two hours every day, work out the inventory requirement of diesel for next 15 days. Also work out fuel cost of diesel for 15 days period if cost of fuel per litre is ₹ 60. Make suitable assumptions if required. Consider diesel density as 0·83 kg/litre. 12

(e) A natural draught cooling tower used in a large cold storage plant receives water from the condenser outlet at a flow rate of 35000 kg/s and 40 °C temperature. The ratio of flow rate of water to air is 1·2 : 1 in the cooling tower. Inlet condition of the air entering the cooling tower is dry-bulb temperature (DBT) of 20 °C and wet-bulb temperature (WBT) of 10 °C. Air leaves the cooling tower at DBT of 35 °C with relative humidity of 90%. For this cooling tower—

(i) draw the inlet and exit conditions of air in psychrometric chart and name the process;

(ii) determine the rate of evaporation of water in kg/s;

(iii) determine the heat carried away by the air;

(iv) determine the maximum possible temperature drop of water realizable.

[Psychrometric Chart is placed at the end] 12

2. *(a)* Glycerine is pumped at a constant rate of 20 litres/s through a straight, 100 mm diameter pipe, 45 m long, inclined at 15° to the horizontal. The gauge pressure at the lower inlet end of the pipe is 590 kPa. Verify that the flow is laminar and calculate the pressure at the outlet end of the pipe and the average shear stress at the wall. (Relative density of glycerine = 1·26 and dynamic viscosity of glycerine = 0·9 Pa s) 20

(b) A very long cylindrical rod of 30 mm diameter is having one of its ends attached to a wall maintained at 500 °C. Entire length of the rod is exposed to atmosphere at 25 °C with convective heat-transfer coefficient of 25 W/m^2 K. Temperature along the length of the rod at (x_1) distance from the base is 400 °C and at (x_1 +10 mm) distance is 390 °C.

(i) Find the thermal conductivity of the rod.

(ii) Find the distance at which temperatures are measured.

(iii) Plot the graph on a plain paper showing the variation of temperature along the length of the rod.

Consider the following relation :

$$\frac{T - T_\infty}{T_b - T_\infty} = e^{-mx}, \quad \text{where } m = \sqrt{\frac{hP}{kA}}$$

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(c) Give general specifications of engine in terms of its power ratings and swept volume for any commonly used two-wheeler and four-wheeler vehicle segment. Why now-a-days multiple inlet and multiple exhaust valves are preferred in engine system of a car over earlier conventional single inlet and single exhaust valve? Also find out for a four-stroke, four-cylinder SI engine operating at 4000 r.p.m., how many number of times the spark will trigger in one minute. 20

3. (a) A furnace is shaped like a long equilateral triangular duct whose side is 1 m. The base surface has an emissivity 0·7 and is maintained at 600 K. The heated left-side surface of emissivity 1·0 is maintained at 1000 K. The right-side surface is fully insulated. Determine the rate at which the energy must be supplied to the heated side externally per unit length of the duct in order to maintain the given conditions. [Take $\sigma = 5{\cdot}67 \times 10^{-8}$ W m^{-2} K^{-4}] 20

(b) Comfort condition for a human being is 20 °C DBT with relative humidity of 50%. Atmospheric conditions at two places are given below during peak summer :

Place	DBT	Relative Humidity
Jaisalmer	45 °C	10%
Chennai	35 °C	80%

(i) Draw the processes in a plain paper applicable to convert the atmospheric condition air to comfort condition.

(ii) Suggest suitable air-conditioning devices to achieve these processes.

(iii) Determine the quantity of moisture needed to be added/removed per kg of air in these places.

[Psychrometric Chart is placed at the end]

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(c) State various losses considered by actual cycle analysis of IC engines. Discuss any one of them in detail. 20

6. (a) For the purpose of project calculations, the total cost of moving a fluid over a distance by pipeline, at a steady flow rate Q, can be broken down into two items. First, the manufacture, laying and maintenance of the pipeline are represented by the cost C_1, which is proportional to D^3 (D = diameter of the pipe). The second item C_2 depends solely upon the energy required to pump the fluid. A preliminary design study for a particular project showed that the total cost was a minimum for $D = 600$ mm. If fuel prices are increased by 150%, and assuming only C_2 is affected, make a revised estimate of the optimum pipe diameter. 20

(b) A refrigeration unit of 250 TR (1 TR = 3·5 kJ/s) capacity using R_12 as the refrigerant operates between −10 °C and 35 °C as evaporator and condenser temperatures respectively. Enthalpy of the refrigerant entering the evaporator is same as saturated liquid enthalpy at the condenser outlet. Dry saturated vapour leaves the compressor. Find the following :

(i) Mass flow rate of the refrigerant required

(ii) Power required to run the compressor assuming isentropic compression

(iii) COP of the unit

(iv) Carnot COP

(v) Heat rejected by the condenser

Refer the following property tables :

T (°C)	P (bar)	v_f (m³/kg)	v_g (m³/kg)	h_f (kJ/kg)	h_{fg} (kJ/kg)	h_g (kJ/kg)	S_f (kJ/kg K)	S_g (kJ/kg K)
−10	2·191	0·000701	0·0821	26·87	156·32	183·19	0·1080	0·7019
35	8·48	0·000786	0·0207	69·56	131·89	201·45	0·2559	0·6839

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(c) What are the different types of work in thermodynamics? State whether flow work is path function or point function. Write the steady flow energy equation for a single stream entering and single stream leaving a control volume. Also discuss steady flow energy equation for the following engineering systems : 20

(i) Throttling device

(ii) Compressor

SECTION—B

5. (a) Discuss why Pelton turbines are unsuitable for low heads. 12

(b) Mention the various advantages and disadvantages of the pulsejet engine and also draw the theoretical and actual pulsejet cycle on a *P-V* diagram. 12

(c) Dry saturated steam at 40 °C enters the surface condenser of a 500 MW thermal power plant having specific steam consumption of 3 kg/kWh. This steam is cooled by the water entering at 25 °C. Minimum terminal temperature difference in the condenser is 7 °C. Water flows through the tubes of internal diameter 3·75 cm and thickness of 3 mm with a velocity of 1 m/s. The overall heattransfer coefficient of the condenser, $U_o = 1500\ W/m^2\ K$.

Determine the following for the condenser :

(i) Mass flow rate of water required in kg/s

(ii) Number of tubes required for the given heat-transfer rate

(iii) Length of each tube

Assume correction factor = 1

Density of water = 1000 kg/m^3

Specific heat of water = 4·2 kJ/kg K

Latent heat of condensation (h_{fg}) = 2407 kJ/kg

Condensed water leaves at saturated condition. 12

(d) State the factors affecting the performance efficiency of solar PV cell. An inventor claims that his 1 m^2 size PV cell panel is capable of producing 2 kW of instantaneous power for a given location in the Indian context. Is his claim valid? Justify.

Assume suitable data wherever necessary. Consider the normally available PV cell efficiency as 15%. 12

(e) With reference to wind turbine, what is tip speed ratio? State its significance. For a wind turbine meant for generation of electricity, how many number of blades are desirable in general? If the tip of a wind rotor blade is travelling at 45 m/s and wind speed is 32 km/h, obtain the tip speed ratio. 12

6. (a) What are surging and stalling in axial flow compressors? Explain briefly how they are developed and their effects. 20

(b) A coal-based 660 MW capacity thermal power plant is having overall efficiency of 42%. It uses 600 kg/s of steam for running the turbine. Coal used in the power plant is having calorific value of 10000 kJ/kg. Fuel to air ratio is 1 : 10 for combustion in the boiler. Find the following : 20

(i) Specific steam consumption in kg/kWh

(ii) Mass flow rate of coal required in Tph (Tonnes per hour)

(iii) Mass flow rate of air required for combustion in kg/s

(iv) Heat required to be supplied to generate one unit of power (in kJ/kWh)

(v) Coal required to be supplied to generate one unit of power (in kg/kWh)

(c) A hotel industry intends to replace its existing electric water heating system with a solar water heating system. The requirement of hot water is around 5000 litres per day. The proposed solar collector area is around 100 m^2 and the average solar radiation falling can be considered as 500 W/m^2. If the collector efficiency is 60%, estimate the reduction in electric bill of the hotel on a yearly average basis. Consider cost of electricity as ₹ 6/kWh. Make suitable assumptions wherever required. Consider average value of length of the day as 10 hours. Also estimate temperature rise of water for given radiation and collector efficiency data. Assume Indian context. Assume electric geyser efficiency as 95%. 20

7. (a) A Parsons turbine runs at 400 r.p.m. with 50% reaction and it develops 75 kW of power per unit mass of steam flow per second. The exit angle of the blades is 20° and the steam velocity is 1·4 times the blade velocity. Find the blade velocity and inlet angle of the blades. 20

(b) (i) Compare the supercritical Rankine cycle and subcritical Rankine cycle used in coal-based thermal power plants.

(ii) How do you estimate the theoretical minimum air required for combustion by knowing the ultimate analysis of the coal? Molecular weight of C, O, H and S can be taken as 12, 16, 1 and 32 units respectively. 20

(c) What is the approximate composition of biogas? State any two factors that govern the biogas production. A family living in a village having 5 cows is interested to set up a biogas plant to meet its cooking requirements. The family has 5 adult persons. Estimate its biogas requirements on daily basis. Also work out the cow dung requirement on daily basis and also find out whether the number of cows available with family is sufficient to meet its requirement. 20
The following data may be useful :

Collectable cow dung per cow = 7 kg (approx.)

Percent of solid mass in cow dung with balance moisture = 18%

Gas yield per kg of dry matter of cow dung = 0·34 m^3/kg of dry mass

Gas requirement for cooking = 0·227 m^3/person/day

8. (a) What do you mean by Net Positive Suction Head (NPSH)? Find the height from the water surface at which a centrifugal pump may be installed to avoid cavitation when atmospheric pressure = 1·01 bar, vapour pressure = 0·022 bar, losses in suction pipe = 1·42 m, effective head of pump = 49 m and cavitation factor = 0·115. 20

(b) Economizer of a power boiler operating at 150 bar pressure receives 500 kg/s of water from boiler feed pump with specific enthalpy of 340 kJ/kg. Superheated steam leaves the boiler at 550 °C with specific enthalpy of 3448·6 kJ/kg. Efficiency of the boiler is 90% and calorific value of the coal used is 10000 kJ/kg. Find the following :

(i) Heat added in economizer, evaporator and superheater in kJ/s

(ii) Percentage of heat added in economizer, evaporator and superheater out of total heat

(iii) Rate of coal consumption in kg/s

Also draw *T*-s plot showing the position of different components and heat added.

For 150 bar pressure, use the following table :

P_s (bar)	T_s (°C)	h_f (kJ/kg)	h_{fg} (kJ/kg)	h_g (kJ/kg)
150	324·24	1610·5	1000	2610·5

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(c) Explain the working principle of solar cooker. What are the challenges in making solar cooker more popular? Also describe the thermal energy storage system of solar energy. 20

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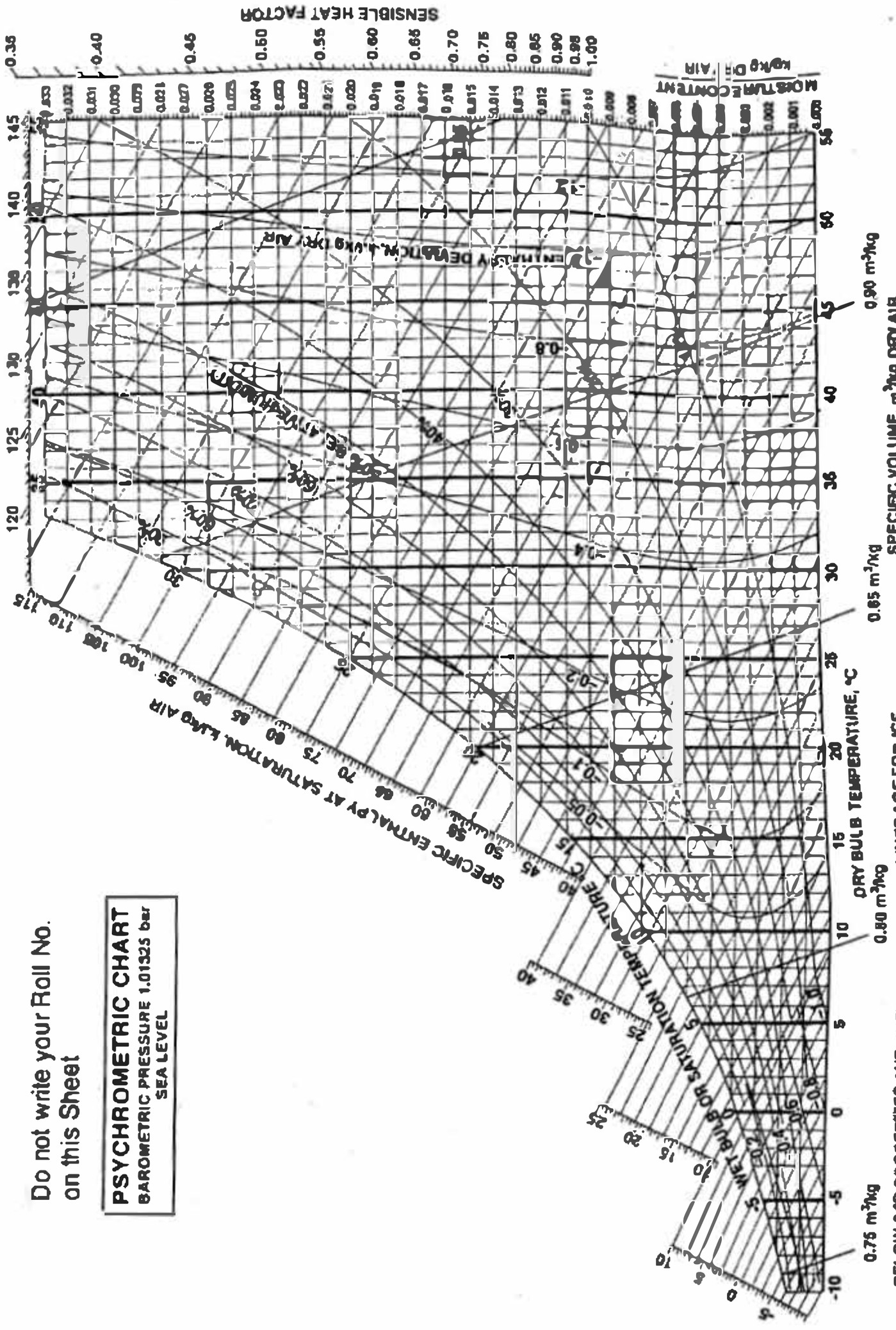
[P.T.O.

Ref. Point for S.H.F. is 25 °C, 50% R.H.



Do not write your Roll No.
on this Sheet

PSYCHROMETRIC CHART
BAROMETRIC PRESSURE 1.01325 bar
SEA LEVEL