C–GEQ–O–NFFB

MECHANICAL ENGINEERING

Paper—II

Time Allowed : Three Hours

Maximum Marks : 200

QUESTION PAPER SPECIFIC INSTRUCTIONS

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

*There are **EIGHT** questions in all, out of which **FIVE** are to be attempted.*

*Question Nos. 1 and 5 are compulsory. Out of the remaining **SIX** questions, **THREE** are to be attempted selecting at least **ONE** question from each of the two Sections A and B.*

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.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

Answers must be written in ENGLISH only.

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

Assume suitable data, if necessary and indicate the same clearly.

Neat sketches may be drawn, wherever required.

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

Psychrometric chart is enclosed.

SECTION—A

Q.1(a) Mention what are the requirements of Ignition System for I.C. Engine. 5

Q.1(b) What do you mean by Scavenging ? Discuss Ideal Scavenging and its limitations. 5

Q.1(c) Explain Air Cooling System for I.C. Engine. 5

Q.1(d) Why is excess air always required to be supplied for combustion ? What is excess air factor ? 5

Q.1(e) Explain what is meant by critical thickness of insulation. 5

Q.1(f) A refrigeration system exhibits a COP one half of the Carnot cycle operating between the same temperature limits. It removes 600 kJ/min from a reservoir at –100 °C while upper temperature is maintained at 200 °C. How much energy is rejected to the high temperature reservoir ? If the refrigerator was reversed to operate as an engine what is the power developed ? 5

Q.1(g) Explain Joule Thomson coefficient. What is inversion temperature ? Show the inversion curve and explain the features. 5

Q.1(h) Two equal parallel black discs 0.5 m diameter are located at 0.25 m apart and directly opposite to each other. If the temperatures of the discs are 200 °C and 50 °C, calculate the net heat exchange between them per square meter area. Assume the view factor for this configuration between the plates = 0.38. 5

Q.2(a) The roof of a hemispherical furnace (ε = 0.8) of radius 1 m is maintained at 800 K, while the temperature of the flat circular floor (ε = 0.5) is at 600 K. Calculate the heat loss. What will be the heat loss if both the floor and the roof would have been black ? 10

Q.2(b) A full load test on a two-stroke engine yielded the following results :

Speed = 440 rpm

Brake load = 490.5 N

IMEP = 3 bar

Fuel Consumption = 5.4 kg/hour

Rise in jacket water temperature = 36 °C

Jacket water flow = 450 kg/hour

Air fuel ratio by mass = 30 : 1

Temperature of exhaust gas = 360 °C

Temperature of the test room = 19 °C

Barometric pressure = 76 cm of Hg

Cylinder diameter = 22 cm

Stroke = 25 cm

Brake diameter = 1.20 m

Calorific value of fuel = 43000 kJ/kg

Proportion of hydrogen by mass in the fuel = 15%

Given,

R_{air} = 0.287 kJ/kgK, C_p of water = 4.18 kJ/kgK

Specific heat of dry exhaust gases = 1 kJ/kgK

Specific heat of dry steam = 2 kJ/kgK

Assume enthalpy of superheated steam to be 3180 kJ/kg. Calculate,

(i) the indicated thermal efficiency

(ii) the specific fuel consumption in kg/kWh

(iii) volumetric efficiency based on atmospheric conditions.

(iv) Draw up a heat balance for the test on the percentage basis indicating the content of each item in the balance. 20

Q.2(c) Calculate the available energy in 40 kg of water at 75°C with respect to the surroundings at 5°C, the pressure being 1 bar. 10

Q.3(a) Helium contained in a cylinder with piston expands according to the law $PV^{1.2} = C$ from 20 m^3, 5 bar, 220 K to a pressure of 2 bar. Calculate the work done and heat transfer during the process. For helium molecular weight = 4.0, C_p = 5.2 kJ/kg K and γ = 1.66. 10

Q.3(b) Air flows at the rate of 0.5 kg/s through an air compressor, entering at 7 m/s velocity, 100 kPa pressure and 0.95 m^3/kg specific volume and leaving at a velocity of 5 m/s, pressure 700 kPa and specific volume 0.19 m^3/kg. The internal energy of the air leaving is 90 kJ/kg less than that at entry. Cooling water in the compressor jackets absorbs 58 kW of heat. Compute the rate of shaft work input to the air and also calculate the ratio of inlet pipe to outlet pipe diameter. 10

Q.3(c) The volumetric analysis of a fuel gas used in a boiler is given as : C_2H_6 = 22.6%, CH_4 = 73.6%, CO_2 = 2.4%, and N_2 = 1.4%. Assuming combustion air to be dry and in 25% excess, find

(i) the molecular weight of the combustion products

(ii) the total gas volume for complete combustion at 260°C, 1.013 bar and

(iii) the dry flue gas analysis based on CO_2, O_2 and N_2. 20

Q.4(a) Explain the characteristic features of a Pressurized Water Reactor (PWR) with the help of a neat sketch. 10

Q.4(b) Explain what do you mean by Rayleigh Flow. What are the assumptions made ? Write down the governing equations for Rayleigh Flow. With the help of h-s diagram, show the occurrence of Normal Shock in Rayleigh Flow. 10

Q.4(c) Derive an expression for the temperature distribution for the case of a homogeneous cylinder with uniformly distributed heat source of strength q''' W/m^3 and hence show that $\frac{T - T_w}{T_c - T_w} = 1 - \left(\frac{r}{R}\right)^2$ where T_w is the surface temperature and T_c is the centre temperature for a one dimensional steady state conduction. 15

Q.4(d) Compare between water tube boiler and fire tube boiler. 5

SECTION—B

Q.5(a) In vapour compression refrigeration for an ideal refrigerant, it is desirable that the evaporator pressure should be positive and near atmospheric. Explain why. 5

Q.5(b) Show that in an ideal gas turbine cycle, the optimum pressure ratio corresponding to which the network output is maximum is given by,

$$r_{optimum} = \left(\frac{T_{max}}{T_{min}}\right)^{1/2}$$

where T_{max} and T_{min} are the maximum and minimum temperatures in the cycle. 5

Q.5(c) Show in the form of a table, how do the following properties change in a sensible cooling process and, a cooling and dehumidifying process. Show the processes on a skeleton psychrometric chart : Dry bulb temperature, Wet bulb temperature, Dew point temperature, specific humidity and relative humidity. 5

Q. 5 (d) Show in the form of a table, how the following flow parameters change in the rotor and stator blades of a 50% reaction axial flow compressor stage :

(i) Absolute velocity

(ii) Static temperature

(iii) Static pressure

(iv) Stagnation temperature and

(v) Stagnation pressure.

Draw the corresponding T-s diagram. 5

Q.5(e) What is a Surge tank ? Explain its importance in a hydroelectric power plant. 5

Q.5(f) Explain what do you mean by Kinetic Energy Correction factor. While considering flow through a round pipe, does its value remain constant both for Laminar and Turbulent flows ? If not, explain why. 5

Q.5(g) Write down the steady flow energy equation and reduce it to apply for the following systems :

(i) Centrifugal water pump

(ii) Steam turbine

(iii) Steam Nozzle. 5

Q.5(h) A stationary mass of gas is compressed without friction from an initial state of 0.3 m^3, 0.105 MPa to a final state of 0.15 m^3 and 0.105 MPa, the pressure remaining constant. During the process, an amount of 37.6 kJ of heat is rejected by the gas. What is the change in internal energy of the gas during the process ? 5

Q. 6(a) An ammonia ice plant operates between a condenser temperature of 35°C and an evaporator temperature of (–15°C). It produces 10 tons of ice per day from water at 30°C to ice at (–5°C). The refrigerant is dry and saturated at the end of compression. Determine :

(i) the capacity of the refrigeration plants in 'TR'

(ii) the mass flow rate of the refrigerant in kg/h

(iii) C.O.P.

Properties of Ammonia :

Sat. Temp.°C	Sat. liquid enthalpy kJ/kg	Sat. vapour enthalpy kJ/kg	Sat. liquid entropy kJ/kg-K	Sat. vapour entropy kJ/kg-K
(–15)	112.3	1426.0	0.457	5.549
35	347.5	1471.0	1.282	4.930

Take : $C_{p_{water}}$ = 4.1868 kJ/kg-K ; $C_{p_{Ice}}$ = 1.94 kJ/kg-K

Latent heat of fusion of ice = 335 kJ/kg 15

Q.6(b) Explain the functions of a steam superheater and reheater in a steam power plant. With the help of T-s diagram, explain how do they affect the performance of the steam power plant. 10

Q.6(c) Water enters a counterflow double pipe heat exchanger at 15°C flowing at a rate of 1300 kg/hr. It is heated by an oil (C_p = 2.000 kJ/kg-K) flowing at the rate of 550 kg/hr with an inlet temperature of 94°C. For an area of 1 m^2 and an overall heat transfer coefficient of 1075 W/m^2K, determine the total heat transfer and outlet temperatures of water and oil.

Assume for counterflow exchanger :

$$\varepsilon = \frac{1 - e^{-NTu\left(1 - \frac{C_{min}}{C_{max}}\right)}}{1 - \frac{C_{min}}{C_{max}} e^{-NTu\left(1 - \frac{C_{min}}{C_{max}}\right)}}$$ 15

Q.7(a) Using Buckingham's π-Theorem method, derive suitable parameters to present the thrust developed by a propeller. Assume that the thrust P depends on the :

(i) angular velocity = ω

(ii) speed of advance = v

(iii) diameter = D

(iv) dynamic viscosity = μ

(v) Mass density = ρ

(vi) Elasticity of the fluid medium which can be denoted by the speed of sound in the medium C. 15

Q.7(b) Explain Reynold's model law and its applications. 5

Q.7(c) A centrifugal compressor running at 16000 rpm takes in air at 17 °C and 1 bar, and compresses it through a pressure ratio of 4 : 1 with an isentropic efficiency of 82 percent. The blades are radially inclined and the slip factor is 0.85. Guide vanes at inlet give the air an angle of pre-whirl of 20° to the axial direction. The mean diameter of the impeller eye is 200 mm and the absolute air velocity at inlet is 120 m/s. Calculate the impeller tip diameter.

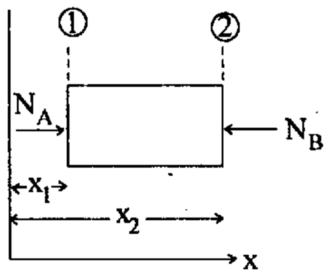
Take $C_p = 1.005$ kJ/kg-K and $\gamma = 1.4$

Draw the T-s diagram and the velocity triangles at the impeller inlet and impeller tip. 20

Q.8(a) Show that for equimolal counter diffusion of a two component system as shown in figure, the no. of moles diffused, N_A is given by the following relation :

$$N_A = \frac{DA(p_{A1} - p_{A2})}{R_o T(x_2 - x_1)}$$

where D is the diffusion coefficient.



Figure

10

Q.8(b) An air-conditioned room is maintained at 25 °C DBT and 50 percent RH. The ambient conditions are 40 °C DBT and 27 °C WBT. The air-handling unit supplies a total of 4500 cmm of dry air which comprises, by weight, 20 percent fresh air and 80 percent recirculated air at the room conditions. The air leaves the cooling coil at 13 °C saturated state. Calculate :

(i) Fresh air load

(ii) Room heat gain

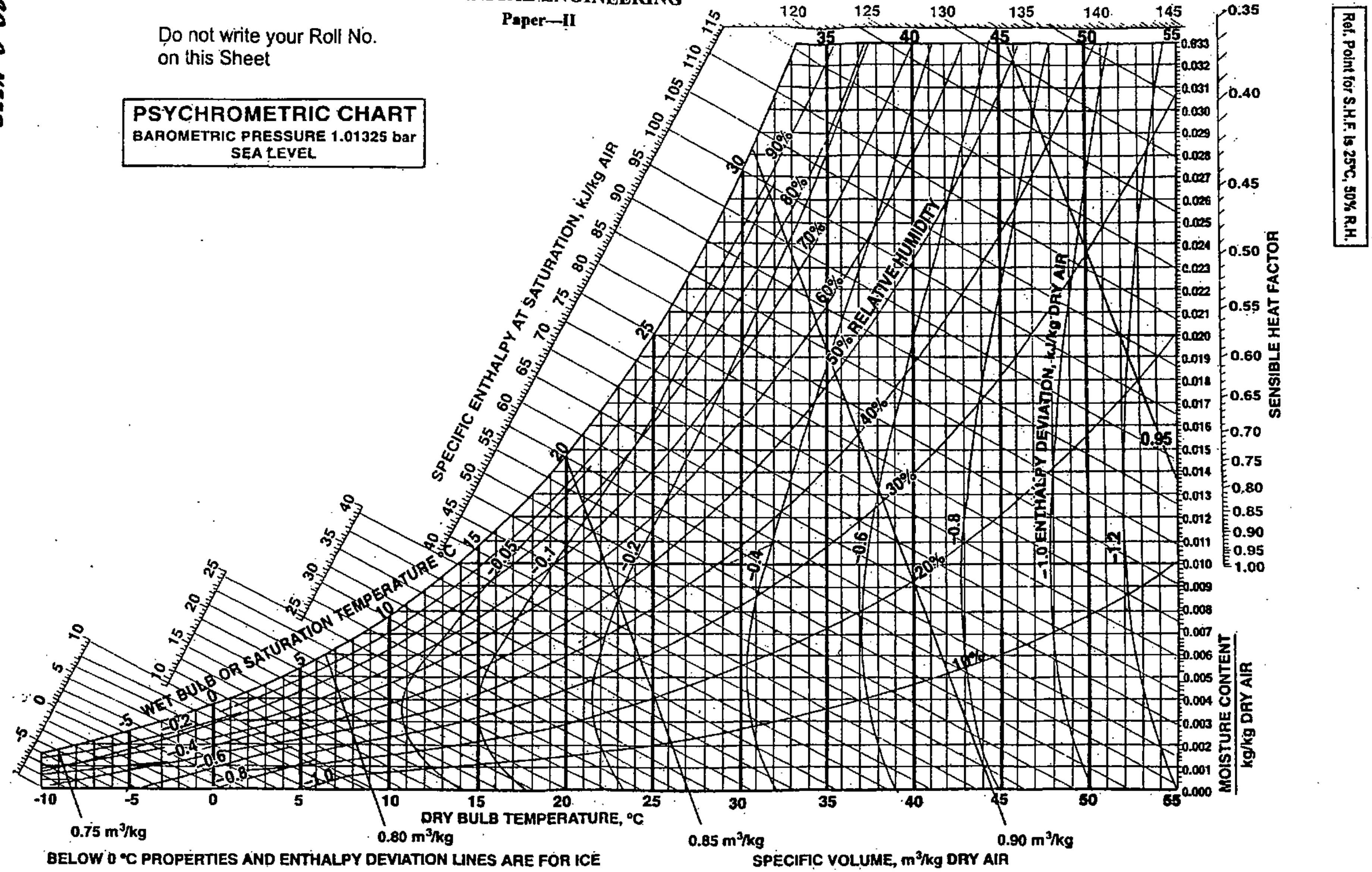
(iii) Total cooling load.

Draw the configuration and show the process on psychrometric diagram. 15

MECHANICAL ENGINEERING

Paper—II

Do not write your Roll No. on this Sheet



Q.8(c) The original value of an equipment is Rs. 5,00,000/- and its salvage value at the end of its useful life of 20 years is Rs. 50,000/-. Find the value of the equipment at the end of 10 years of its use by the following methods :

(i) Straight line depreciation and

(ii) Sinking fund depreciation

when it is compounded annually at the rate of 8%. 10

Q.8(d) What is the function of the draught system in a steam power plant ? Derive an expression to show that for a given chimney height and ambient air temperature, the draught is a function of the flue gas temperature. 5