I.F.S. EXAM-2016

C-MNS-S-MLE

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.*

*Questions no. **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

Q1. (a) Derive the following thermodynamic relation : *10*

$$c_p - c_v = - T\left(\frac{\partial v}{\partial T}\right)_p^2 \left(\frac{\partial p}{\partial v}\right)_T$$

(b) Discuss the effect of the following on the flame speed during combustion in an SI engine : *10*

(i) Compression ratio

(ii) Intake pressure

(iii) Engine speed

(iv) Air-fuel ratio

(v) Engine load

(c) A copper wire having a diameter of 2 mm is exposed to a convection environment with heat transfer coefficient, $h = 5000\ W/m^2$-K and environment temperature, $T_\infty = 100°C$. What current must be passed through the wire to produce a centre temperature of 150°C ? Specific electrical resistance of copper is 1·67 μΩ cm. Thermal conductivity of copper is 386 W/m-K. *10*

(d) The following data are given for a single cylinder four stroke cycle oil engine :

Cylinder diameter = 18 cm, stroke = 36 cm, speed of the engine = 286 rpm, brake torque = 375 Nm, IMEP = 7 bar, fuel consumption = 3·85 litres/hr, specific gravity of fuel = 0·8, calorific value of fuel = 44·5 MJ/kg. A/F = 25 : 1, ambient air temperature = 21°C, c_p of gases = 1·2 kJ/kg-K, exhaust gas temperature = 415°C, cooling water circulated = 4·2 kg/min, rise in temperature of cooling water = 28·5°C. Find the mechanical and indicated thermal efficiency and draw a heat balance sheet on percentage basis. *10*

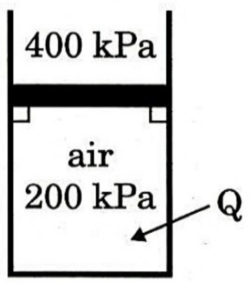
Q2. (a) The readings of two thermometers A and B agree at ice point and steam point as 0°C and 100°C. The two temperature readings are related by the following expression :

$$t_A = a + bt_B + ct_B^2$$

where a, b and c are constants. In a constant temperature bath, the temperatures are shown as 51°C on thermometer A and 50°C on thermometer B. Determine the reading on thermometer B when the thermometer A reads 65°C. Can you comment which of the two thermometers is correct ? *20*

(b) A 40 kg rigid steel tank of 1000 litre capacity contains air at 500 kPa pressure and both tank and air are at 20°C temperature. The tank is connected to a line flowing air at 2 MPa pressure and 20°C temperature. The valve is opened, allowing air to flow into the tank until the pressure reaches 1·5 MPa and it is then closed. Assume the air and tank are always at the same temperature and the final temperature is 35°C. Find the final air mass that entered the tank and the heat transfer. Specific heat of steel = 0·46 kJ/kg-K. *20*

Q3. (a) A piston-cylinder device is shown in the figure. The piston resting on top of a set of stops, initially contains 3 kg of air at 200 kPa and 27°C temperature. The mass of piston is such that a pressure of 400 kPa is required to move it. Heat is now transferred to the air until the volume is doubled. Determine the work done by the air and the amount of heat transfer, and show the process on P-v diagram. The average c_p for air is 0·8 kJ/kg-K, which remains constant throughout any process. *20*



(b) A petrol engine having stroke volume of 0·0012 m^3 and compression ratio of 5·5 compresses the mixture to 8·5 bar and 350°C. Ignition is started so that the pressure rises along a straight line during explosion and attains its higher value of 28 bar after the piston has travelled 1/30 of working stroke. The air-fuel ratio is 16 : 1. Calorific value of the fuel is 44 MJ/kg and c_p = 0·962 kJ/kg-K. Find the heat loss per kg of charge during explosion. *20*

Q4. (a) Derive the following expression for the thermal efficiency of an air standard diesel cycle : *20*

$$\eta_{th} = 1 - \frac{1}{\gamma} \cdot \frac{1}{r^{\gamma-1}} \cdot \left(\frac{\rho^{\gamma} - 1}{\rho - 1} \right)$$

r = compression ratio; ρ = cut-off ratio, $\gamma = \frac{c_p}{c_v}$.

(b) Calculate the proportion of the heat of fuel carried away by the flue gases for the following data :

Coal with CV of 29·6 MJ/kg of coal has a composition by mass C = 78%, H = 5%, O_2 = 8%, S = 2%, N_2 = 2% and remainder is ash. It is burnt in a furnace with 50% excess air. The flue gases leaving the chimney are at 327°C and the atmospheric temperature is 15°C. Assume perfect combustion. The specific heat, c_p, for air and dry products is 1005 J/kg-K and 1045 J/kg-K respectively. The heat carried away per kg of moisture in the flue gases is 2990 kJ/kg. Composition of air by mass O_2 = 23% and N_2 = 77%. *20*

SECTION B

Q5. (a) Air at 20 kPa and 5°C temperature enters a 25 mm diameter tube at a velocity of 1·5 m/s. Using a flat-plate analysis, estimate the distance from the entrance at which the flow becomes fully developed. Viscosity, $\mu = 1{\cdot}864 \times 10^{-5}$ Pa-s. *10*

(b) Five grams of water vapour per kilogram of atmospheric air at 35°C dry bulb temperature and 60% relative humidity is removed and the dry bulb temperature of air after removing the water vapour becomes 25°C. Find for the air at final stage

(i) the relative humidity, and

(ii) the dew point temperature.

Assume, condition of atmospheric air is 35°C dry bulb temperature and relative humidity is 60%. Atmospheric pressure is 100 kPa.

The saturation properties of water are given in the following table : *10*

Temp, °C	5	10	15	20	25	30	35	40
Sat. pressure, kPa	0·87	1·23	1·71	2·34	3·17	4·25	5·63	7·38

(c) Define blade efficiency (η_b) of a single stage steam turbine and prove that the maximum blade efficiency for a single stage steam turbine, $(\eta_b)_{max} = \cos^2 \alpha$, where α is the blade inlet angle. *10*

(d) A solid sphere of diameter 10 cm is heated to 1000°C and suspended in a room having room temperature of 30°C. Compute the time taken by the sphere to cool to 500°C assuming emissivity of sphere 0·1 and density 8·68 gm/cc. Take specific heat = 0·098 J/kg-K. *10*

Q6. (a) Air at 200 kPa pressure and 200°C is heated as it flows through a tube with a diameter of 25 mm at a velocity of 10 m/s. Calculate the heat transfer per unit length of tube, if a constant-heat-flux condition is maintained at the wall and the wall temperature is 20°C above the air temperature, all along the length of the tube. How much would the bulk temperature increase over a 3-m length of the tube ? For air at 200°C temperature : viscosity, $\mu = 2{\cdot}57 \times 10^{-5}$ Pa-s, thermal conductivity, $k = 0{\cdot}0386$ W/m-K, constant specific heat, $c_p = 1025$ J/kg-K. *20*

(b) A long cylinder having a diameter of 2 cm is maintained at 600°C and has an emissivity of 0·4. Surrounding the cylinder is another long, thin-walled concentric cylinder having a diameter of 6 cm and an emissivity of 0·2 on both the inside and outside surfaces. The assembly is located in a large room having a temperature of 27°C. Calculate the net radiant energy lost by the 2-cm-diameter cylinder per metre of length. Also calculate the temperature of the 6-cm-diameter cylinder. Stefan-Boltzmann Constant, $\sigma = 5{\cdot}67 \times 10^{-8}$ W/m^2-K^4. *20*

Q7. (a) A 25 TR capacity ammonia vapour compression refrigerating machine works between 26°C and – 20°C. The ammonia leaves the compressor dry and saturated. Liquid ammonia is undercooled to 22·5°C, before throttling. Find the theoretical COP of the machine. The c_p of saturated ammonia liquid is 4·72 kJ/kg-K. The c_p for ammonia vapour is 2·8 kJ/kg-K. Find the COP of the cycle and the mass flow rate of ammonia in kg/min. *20*

	Liquid		Vapour	
t,°C	h, kJ/kg	s, kJ/kg-K	h, kJ/kg	s, kJ/kg-K
26	322·5	1·4248	1448·0	5·3076
– 20	108·6	0·6538	1437·6	5·9041

(b) An open cycle gas turbine plant operates with a pressure ratio of 4·5 while using 82 kg/min of air and 1·4 kg/min of fuel. The net output of the plant is 200 kW when 230 kW is needed to drive the compressor. Air enters the compressor at 100 bar and 15°C and combustion gases enter the turbine at 765°C. Assuming specific heat of air and combustion gases as 1·005 kJ/kg-K and 1·128 kJ/kg-K respectively, the index of compression 1·4, the index of expansion 1·34 and mechanical efficiency for both the compressor and turbine as 0·98, estimate

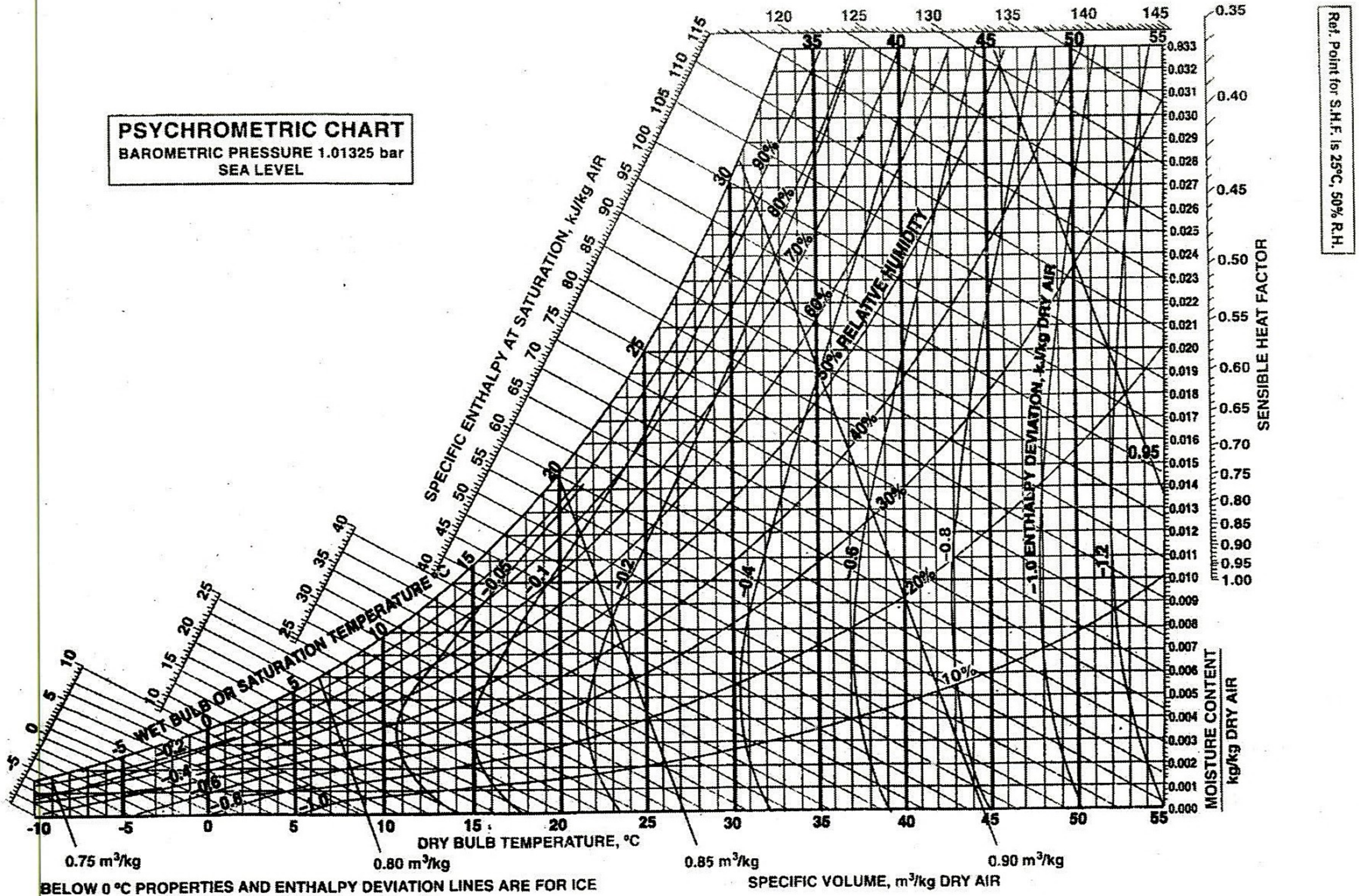
(i) the isentropic efficiency of the compressor,

(ii) the isentropic efficiency of the turbine, and

(iii) the overall efficiency of the plant. *20*

Q8. (a) Steam flows from the nozzles of a single row impulse turbine with a velocity of 450 m/s at a direction which is inclined at an angle of 16° to the peripheral velocity. Steam comes out of the moving blades with an absolute velocity of 100 m/s in the direction at 110° with the direction of blade motion. The blades are equiangular and the steam flow rate is 6 kg/s. Determine the power loss due to friction. *20*

(b) State Buckingham π-theorem and hence obtain an expression for the thrust developed by a propeller which depends upon the angular velocity ω, approach velocity v, dynamic viscosity μ, density ρ, propeller diameter D and the compressibility of the medium measured by the local velocity of sound c. *20*


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