वियोज्य *DETACHABLE*

I.F.S. EXAM-(M)2017

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.

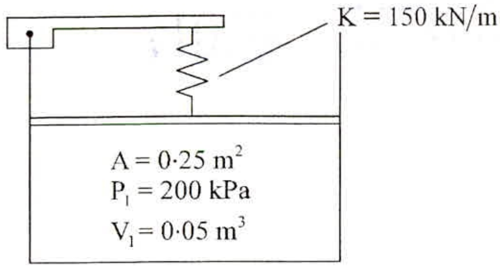
1 bar = 10^5 pascals

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

Psychrometric chart is enclosed.

SECTION 'A'

1. (a)



A piston-cylinder device contains $0{\cdot}05\ m^3$ of a gas initially at 200 kPa. At this state, a linear spring that has a spring constant of 150 kN/m is touching the piston but exerting no force on it. Now heat is transferred to the gas, causing the piston to rise and to compress the spring until the volume inside the cylinder doubles. If the cross-sectional area of the piston is $0{\cdot}25\ m^2$, determine (i) the final pressure inside the cylinder, (ii) the total work done by the gas. 10

1. (b) Calculate the approximate Grashof number and state if the flow is laminar or turbulent for the following :

(i) A central heating radiator, 0·6 m high with a surface temperature of 75°C in a room at 18°C, $\rho = 1{\cdot}2\ kg/m^3$, $P_r = 0{\cdot}72$ and $\mu = 1{\cdot}8 \times 10^{-5}$ kg/ms.

(ii) A horizontal oil sump with a surface temperature of 40°C, 0·4 m long and 0·2 m wide containing oil at 75°C. Take $\rho = 854\ kg/m^3$, $P_r = 546$, $\beta = 0{\cdot}7 \times 10^{-3}\ K^{-1}$ and $\mu = 3{\cdot}56 \times 10^{-2}$ kg/ms. 10

1. (c) Discuss the causes, effects and the actions to be taken to remove/reduce the following emissions from I.C. engines :

(i) Oxides of Nitrogen (NO_x)

(ii) Smoke

(iii) Carbon Monoxide (CO)

(iv) Unburned Hydrocarbons (HC)

(v) Sulphur Oxides (SO_2) 10

1. (d) A chimney has a height of 100 metres. For the maximum discharge condition, calculate the temperature of the chimney gases and the draught produced if the air supplied per kg of fuel is 18 kg. Also determine the efficiency of this chimney as an instrument for creating the draught, if the temperature of chimney gases in artificial draught system is limited to 120°C. Take the boiler house temperature as 40°C and the specific heat of flue gases as 1·005 kJ/kg K. 10

2. (a) A four-cylinder four-stroke S.I. engine with 80 mm bore and 90 mm stroke, runs at 4000 rpm and uses a fuel having 84% carbon and 16% hydrogen by mass. The volumetric efficiency of the engine at that speed is 80%. The ambient conditions are : pressure = 1·0 bar, temperature = 25°C. The depression at the venturi throat is 0·06 bar. The actual quantity of air supplied is 0·95 of the stoichiometric value. Calculate the fuel flow rate, the air velocity at the throat and the throat diameter.

Take : R(air) = 287 J/(kg K), R(fuel vapour) = 98 J/(kg K)
C_p = 1005 J/(kg K), γ = 1·4 and coefficient of discharge at venturi throat as 1.
20

2. (b) A counterflow, concentric tube heat exchanger is used to cool the lubricating oil for a large industrial gas turbine engine. The flow rate of cooling water through the inner tube (D_i = 25 mm) is 0·2 kg/s, while the flow rate of oil through the outer annulus (D_o = 45 mm) is 0·1 kg/s. The oil and water enter at temperature of 100 and 30°C respectively. How long must the tube be made if outlet temperature of the oil is to be 60°C ? State assumptions made, if any. Comment on the magnitude of length of tube.
20

Properties of Oil

Temperature °C	C_p J/kg K	μ N.s/m^2	K W/mK	P_r
100	2250	$1{\cdot}41\times10^{-2}$	0·137	300
80	2131	$3{\cdot}25\times10^{-2}$	0·138	546
60	2035	$8{\cdot}36\times10^{-2}$	0·141	1205

Properties of Water

Temperature °C	C_p J/kg K	μ N.s/m^2	K W/mK	P_r
30	4178	769×10^{-6}	0·620	5·20
35	4178	725×10^{-6}	0·625	4·85
40	4179	631×10^{-6}	0·634	4·16

Nusselt number for fully developed laminar flow in a circular tube annulus with one surface insulated and the other at constant temperature :

D_i/D_o	Nu_i	Nu_o	D_i/D_o	Nu_i	Nu_o
0	–	3·66	0·25	7·37	4·23
0·05	17·46	4·06	0·50	5·74	4·43
0·10	11·56	4·11	≈1·00	4·86	4·86

3. (a) The output of a three stage gas turbine is 30 MW at the shaft coupling at an entry temperature of 1500 K. The overall pressure ratio across the turbine is 11 and efficiency 88%. If the pressure ratio of each stage is same, determine :

(i) pressure ratio of each stage

(ii) polytropic efficiency

(iii) the mass flow rate

(iv) the efficiency and power of each stage

The properties of the working medium are the same as of air ($\gamma = 1{\cdot}4$, $C_p = 1{\cdot}005$ kJ/kg K). Assume an efficiency of 91% to take into account shaft losses due to disc and bearing friction. 20

3. (b) A retail shop located in a city at 30° N latitude has the loads as given below :

Room Sensible heat – 58·15 kW
Room Latent heat – 14·54 kW

The summer outside and inside design conditions are :

Outside : 40°C DB, 27°C WB
Inside : 25°C DB, 50% RH

70 m^3/min of ventilation air is used. Determine the following :

(i) Ventilation load

(ii) Grand total heat

(iii) Effective sensible heat factor

(iv) Apparatus dew point

(v) Dehumidified air quantity

(vi) Condition of air entering and leaving apparatus

Given a choice, what bypass factor (BF) would you choose from 0·05, 0·1, 0·15, 0·20. Give justification for selection of BF. Solve the problem using BF of 0·15. Use of Psychrometric chart is permitted. 20

MECHANICAL ENGINEERING
Paper II

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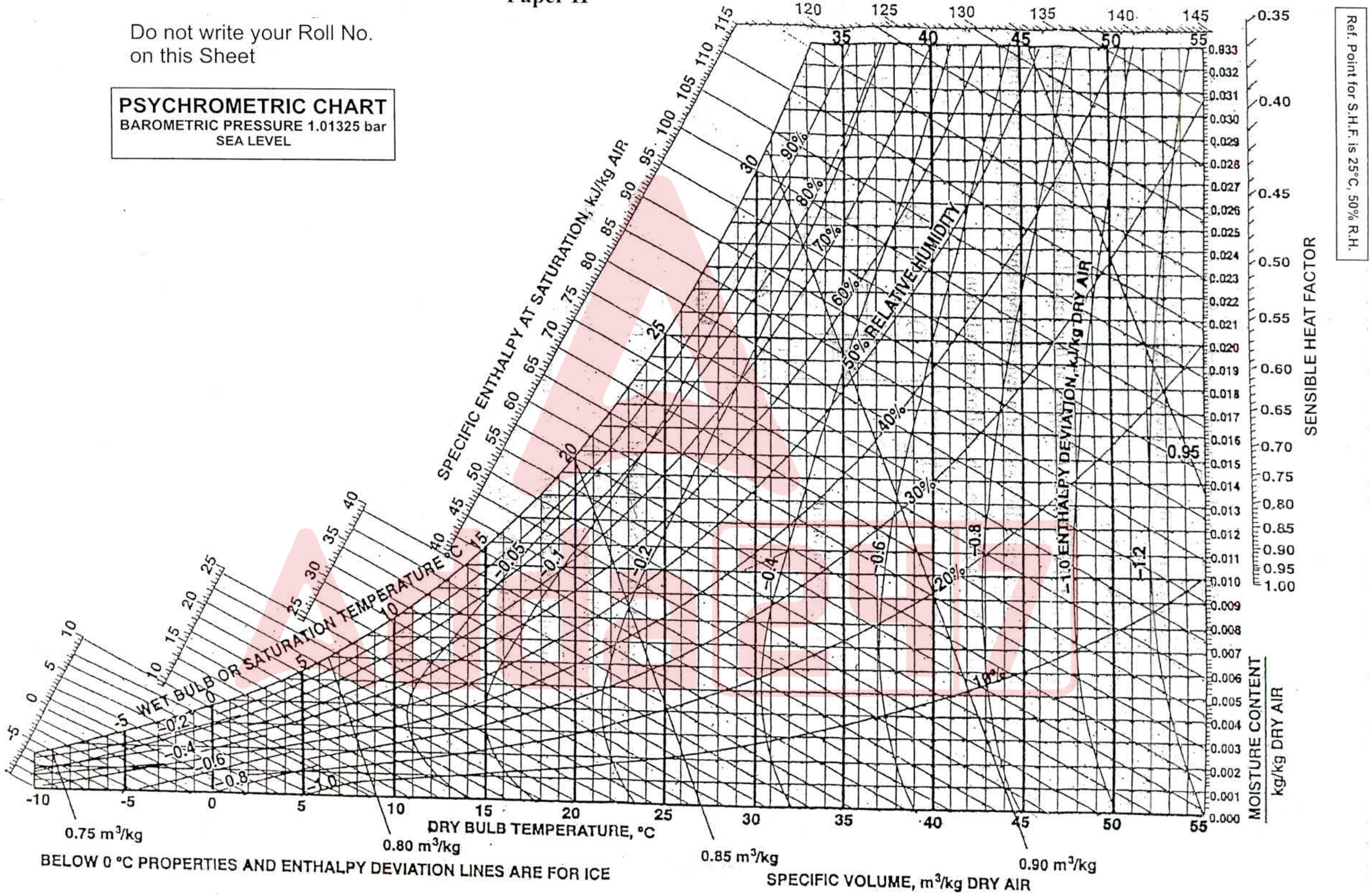

5

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4. (a) Describe the working principle of Jerk type injection pump with the help of neat diagram. Show the position of the helix for various load conditions. 20

4. (b) In a reversed Carnot refrigerator system of 1TR cooling capacity running on perfect gas, heat is absorbed at –10°C and rejected at 50°C. Find the states at all the points of the cycle, mass flow rate, volume flow rates and COP. The maximum pressure ratio is 5 and the pressure at inlet to the isentropic process is standard atmospheric pressure. Take $C_p = 1{\cdot}005$ kJ/kg K, $R = 0{\cdot}287$ kJ/kg K and $\gamma = 1{\cdot}4$. Plot the cycle on p–v and T–s diagrams. Comment on the area of p–v diagram. 20

SECTION 'B'

5. (a) A 3 cm OD pipe is to be covered with two layers of insulation, each having a thickness of 2·5 cm. The average thermal conductivity of one insulation is five times that of the other. Determine the percentage decrease in heat transfer if the better insulating material is next to the pipe than if it is the outer layer. Assume that the outside and inside surface temperatures of the composite insulation are fixed. 10

5. (b) Air is compressed steadily by a reversible compressor from an inlet state of 100 kPa and 300 K to an exit pressure of 900 kPa. Determine the compressor work per unit mass for (i) Isentropic compression with $\gamma = 1{\cdot}4$; (ii) Polytropic compression with $n = 1{\cdot}3$; (iii) Isothermal compression and (iv) Ideal two-stage compression with intercooling with a polytropic exponent of 1·3. 10

5. (c) Discuss the effect of the following variables on ignition lag :

(i) Nature of fuel and air/fuel ratio

(ii) Initial temperature and pressure

(iii) Spark timing

(iv) Turbulence and engine speed

(v) Gap between electrodes of the spark plug 10

5. (d) Determine the pressure ratio developed and the power required to drive a centrifugal compressor (impeller diameter = 45 cm) running at 7200 rpm. Take zero swirl at entry and $T_{01} = 288$ K. Assume isentropic flow with no shock, and radially tipped impeller blades. Take $C_p = 1{\cdot}005$ kJ/kg K and $\gamma = 1{\cdot}4$. 10

6. (a) A food compartment of a refrigerator is maintained at 4°C by removing heat from it at a rate of 360 kJ/min. If the required power input to the refrigerator is 2 kW, determine (i) the C.O.P. of the refrigerator and (ii) the rate of heat rejection to the room that houses the refrigerator.

Also state the Kelvin Plank and Clausius statement being used for second law of thermodynamics. Further define C.O.P. of refrigerator, C.O.P. of heat pump and show that

$$(\text{C.O.P.})_{\text{heat pump}} = 1 + (\text{C.O.P.})_{\text{refrigerator}}$$ 20

6. (b) The internal energy of a certain substance is expressed by the equation

$$u = 3{\cdot}62\ pv + 86$$

where u is in kJ/kg, p in kPa and v is in m^3/kg.

A system composed of 5 kg of this substance expands from an initial pressure of 550 kPa and a volume of $0{\cdot}25\ m^3$/kg to a final pressure of 125 kPa, in a process in which pressure and volume are related by $pv^{1{\cdot}2}$ = constant. If the expansion process is quasistatic, determine work (W), change in internal energy and heat transferred in this process. 10

6. (c) The performance of an air-conditioner unit rated as 40 Tons, seems to be indicating poor cooling. The test on heat rejection to atmosphere in its condenser shows the following :

Cooling water flow	:	4 L/s
Water inlet temperature	:	30°C
Water outlet temperature	:	40°C
Power input to motor	:	40 kW
Efficiency of motor	:	95%
Specific heat of water	:	4·186 kJ/kg K

Calculate the actual refrigerating capacity of the unit and conclude on whether the unit is giving poor cooling. 10

7. (a) A four-cylinder S.I. engine has a bore of 60 mm and a stroke of 85 mm. It runs at 3000 rpm and is tested at this speed against a brake which has a torque arm of 0·35 m. The net brake load is 160 N and the fuel consumption is 6·6 lit/hr. The specific gravity of the fuel used is 0·78 and it has a lower calorific value of 44,000 kJ/kg. A Morse-test is carried out and the cylinders are cut out in the order 1, 2, 3, 4 with the corresponding brake loads of 114, 110, 112 and 116 N respectively. Calculate for this speed the bp, the bmep, the bte, the bsfc, the ip, the mechanical efficiency and the imep. 20

7. (b) The temperature distribution across a wall, having thickness of 1 m, at an instant of time is given as :

$$T(x) = 900 - 300x - 50x^2$$

where T is in degree celsius and x is in metres. The uniform heat generation of $1000\ W/m^3$ is present in the wall of area $10\ m^2$ having density $\rho = 1600\ kg/m^3$, thermal conductivity $k = 40$ W/mk and specific heat $C = 4$ kJ/kg K.

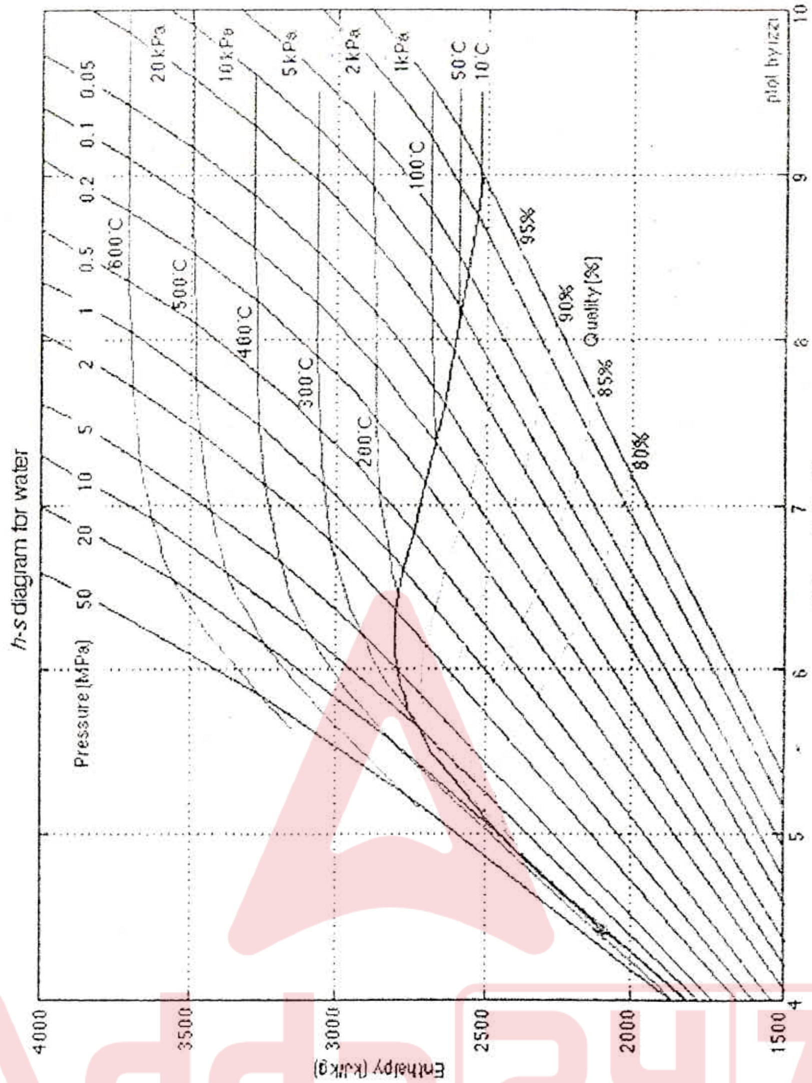
Determine (i) the rate of heat transfer entering the wall and leaving the wall.

(ii) the rate change of internal energy of the wall.

(iii) the time rate of temperature change at $x = 0$ and at $x = 0{\cdot}5$ m. 20

8. (a) Steam is supplied by the steam generator at 90 bar and 500°C. After the expansion in the turbine to 10 bar a portion of the steam is bled for regenerative feed heating and the remaining is passed on to the reheater from where it returns to the turbine at 500°C. Expansion further continues to 0·07 bar. For 1 kg of mass of steam supplied at generator inlet, calculate (a) heat supplied, (b) heat rejected, (c) net work done, (d) thermal efficiency, and (e) steam rate in kg/kWh. Assume the specific volume of water as $0{\cdot}001074\ m^3$/kg. Specific enthalpy of saturated liquid at 0·07 bar and 10 bar are 163·38 kJ/kg and 762·61 kJ/kg respectively. 20

MOLLIER CHART



8. (b) The handle of a saucepan, 30 cm long and 2 cm in diameter is partially immersed in boiling water at 100°C. The average unit conductance over the handle surface is 7·35 W/m^2 K in the kitchen air at 24°C. The cook is likely to grasp the last 10 cm of the handle and hence, the temperature of this portion should not exceed 32°C. What should be the material conductivity of handle ? The handle may be treated as a fin of insulated tip. 10

8. (c) An artificial spherical satellite flies around the earth. Calculate the temperature of the satellite surface, assuming that there are no heat sources and surface temperature is uniform all over the surface. The solar radiation reflected from the earth and radiation emitted from the earth should also be ignored.

(i) If $\alpha_s = 0{\cdot}2$ and $\in = 0{\cdot}1$

(ii) If surface of the satellite is gray

(iii) Find the ratio $\alpha_s/\in$, when the temperature of the satellite surface becomes 30°C. The incident solar radiation is 1500 W/m^2. 10