Indian Forest Service Examination, 2010

0362

B-JGT-K-NFB

MECHANICAL ENGINEERING

Paper II

Time Allowed : Three Hours | *Maximum Marks : 200*

INSTRUCTIONS

Candidates should attempt questions 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.

A psychrometric chart is attached to, and forms part of this question paper.

SECTION A

1. (a) For a gas, the equation of state is expressed as below over a certain range of temperatures and pressures : $V = \frac{RT}{P} - \frac{a}{T^3}$, where a is constant. Prove that the change in enthalpy is given by $\frac{4a}{T^3}(P_1 - P_2)_T$ for isothermal process. Also find out the expression for change of entropy. *8*

(b) What is the function of a catalyst in the catalytic converter for smoke emission control ? What are the oxidation and reduction processes that take place ? Why is unleaded petrol preferred in cars fitted with catalytic converter ? *8*

(c) What do you mean by compact heat exchanger ? What are their applications ? *8*

(d) Describe the main sources of evaporative emissions in a S.I. engine. *8*

(e) A metal plate size 500 mm × 800 mm × 20 mm and thermal conductivity 30 Watt/m-C is maintained at 250°C. Air at 20°C is blowing over the plate. If convection heat transfer coefficient is 25 W/m^2C and 200 W is lost by the plate by radiation, compute the inside temperature. *8*

2. (a) Consequent upon first law of thermodynamics, show that the heat is a path function. *7*

(b) Using pressure – time diagram, explain the combustion process in diesel engine. *8*

(c) The following data relates to a two-cylinder four-stroke coal gas engine :

Bore and stroke of cylinder = 380 mm and 585 mm respectively

At 240 rpm, torque developed = 5·16 kNm

Coal gas to air mixture ratio = 1 to 7 by volume

Estimated volumetric efficiency = 85%

Net calorific value of coal gas = 16800 kJ/kg

Calculate the brake power, brake mean effective pressure, piston speed in meter per second and brake thermal efficiency. *20*

(d) Draw the labelled schematic diagram of a common rail injection system in a C.I. engine. *5*

3. (a) The cylinder volume of an I.C. engine is 3000 cm^3. It contains products of combustion in gaseous form, which can be assumed to be an ideal gas. The combustion products, just before the exhaust valve opens, are at a pressure of 6 bar and temperature of 1123 K. Assuming specific heats at constant volume and constant pressure as 0·718 and 1·005 kJ/kg-K respectively, analyse and discuss the availability of specific energy of the gas. The initial pressure and temperature of gas can be taken as 1 bar and 15°C respectively. *10*

(b) What are the characteristics of liquid oil, coal-oil mixture, natural and petroleum gas fuels ? What are their major constituents ? Where are they suitably used ? *15*

(c) A sample of coal contains 93% carbon, 6% hydrogen and rest ash. A test was conducted in a Bomb calorimeter using 0·92 kg of coal burnt and following data obtained :

Weight of water taken = 550 gm, Water equivalent of Bomb calorimeter = 2200 gm, Rise in temperature of water = 2·42°C, Fuse wire correction = 10 cal, Acid correction = 50 cal. Taking latent heat of condensation of steam as 530 cal/gm, calculate gross and net calorific value of coal. *15*

4. (a) The air-conditioning unit of a pressurised jet aircraft receives its air from the compressor driven by the engine at a pressure of 1·4 bar. The pressure and temperature of the surrounding air at the height of the aircraft are 0·2 bar and 225 K, respectively. The air-conditioning unit consists of a secondary compressor and a turbine mounted on the same shaft. The pressure and temperature of air leaving the turbine are 1 bar and 275 K. Calculate the pressure after the secondary compressor and temperature of air at the exit from the cooler. Assume that all processes are reversible adiabatic. *20*

(b) Cold air is to be supplied for a library at a rate of 100 m^3/min. The air is to enter the building at 20°C with 40% relative humidity. Suppose the atmospheric air is available at 35°C with 70% relative humidity, suggest a suitable air-conditioning system and estimate the rates of cooling and heating required. *20*

SECTION B

5. (a) Describe in brief how the fly ash is disposed off by 'dry system' and 'wet system'. What problems are caused by present systems of fly ash disposal ? Give the applications of fly ash. *8*

(b) Name the essential parts of a centrifugal compressor along with their functioning. Sketch a simple figure of a 'diffuser' and write down the names of important parts. *8*

(c) With the help of figure, describe the working of 'Velox boiler'. Enumerate its advantages. *8*

(d) Derive the expression for temperature distribution for a fin insulated at the end. The base temperature of fin is constant. Write typical application for this type of fin. *8*

(e) Describe the desirable properties of refrigerants suitable for ice plant applications. Name a few of these. *8*

6. (a) Prove that the simple arithmetic mean temperature difference gives results within 5% compared to LMTD when the ratio of end temperature differences is not more than 2·2. *7*

(b) A vapour compression refrigerator uses R-12 as refrigerant and the liquid evaporates in the evaporator at –15°C. The temperature of this refrigerant at the delivery from the compressor is 15°C when the vapour is condensed at 10°C. Find the coefficient of performance if (i) there is no under cooling (ii) the liquid is cooled 5°C before expansion by throttling. Take specific heat at constant pressure for the superheated vapour as 0·64 kJ/kg-K and that for liquid as 0·94 kJ/kg-K. The properties of refrigerant are as given below : *20*

Temp °C	Enthalpy in kJ/kg		Entropy in kJ/kg-K	
	Liquid	Vapour	Liquid	Vapour
–15	22·3	180·88	0·0904	0·7051
+10	45·4	191·76	0·1750	0·6921

(c) What are the methods used to reduce the heat radiation between two parallel plates ? Write the process, material and specific application of one such technique. *7*

(d) Define the second law efficiency of a vapour compression cycle. Derive its efficiency in terms of COP. *6*

7. (a) A conical diffuser has entry and exit diameters of 15 cm and 30 cm respectively. The pressure, temperature and velocity of air at entry are 0·69 bar, 340 K and 180 m/s respectively. Determine

(i) the exit pressure

(ii) the exit velocity

(iii) the force exerted on the diffuser walls.

For solution the following table may be used. Suffix '0' is corresponding to stagnation pressure values. The star (*) values are critical values corresponding to M = 1. M is Mach number and M* is corresponding to critical velocity of sound (c*). *15*

Isentropic flow of a perfect gas (γ = 1·4)

M	M*	T/T_0	p/p_0	A/A*	F/F*	Ap/A^*p_0
0·00	0·000	1·000	1·000	∞	∞	∞
0·05	0·0548	0·999	0·998	11·592	9·158	11·571
0·10	0·1094	0·998	0·993	5·822	4·624	5·781
0·15	0·1640	0·996	0·984	3·910	3·132	3·849
0·20	0·218	0·992	0·973	2·964	2·400	2·882
0·25	0·272	0·987	0·957	2·403	1·973	2·301
0·30	0·326	0·982	0·939	2·035	1·698	1·912
0·35	0·378	0·976	0·918	1·778	1·509	1·634
0·40	0·431	0·969	0·895	1·590	1·375	1·424
0·45	0·483	0·961	0·870	1·448	1·276	1·261
0·50	0·534	0·952	0·843	1·339	1·203	1·129
0·55	0·585	0·943	0·814	1·255	1·147	1·022
0·60	0·635	0·933	0·784	1·188	1·105	0·932
0·65	0·684	0·922	0·753	1·135	1·073	0·855
0·70	0·732	0·910	0·721	1·094	1·049	0·789
0·75	0·779	0·898	0·688	1·062	1·031	0·731
0·80	0·825	0·886	0·656	1·038	1·018	0·681

(b) The maximum demand of a power station is 96,000 MW and daily load curve is described as follows :

Time hours	0 – 6	6 – 8	8 – 12	12 – 14	14 – 18	18 – 22	22 – 24
Load MW	48	60	72	60	84	96	48

(i) Determine the load factor of power station.

(ii) What is the load factor of standby equipment rated at 30 MW that takes up all load in excess of 72 MW ? Also calculate its use factor. *15*

(c) What do you mean by depreciation cost ? Name the methods used to calculate the depreciation cost. Explain these methods. *10*

8. (a) The following data refers to a stage of an impulse reaction turbine :

Steam velocity coming out of nozzle = 245 m/s; nozzle angle = 20°, blade mean speed = 145 m/s; speed of rotor = 3000 rpm; blade height = 10 cm; specific volume of steam at nozzle outlet and blade outlet are 3·45 m^3/kg and 3·95 m^3/kg respectively. Power developed by turbine = 390 hp; efficiency of nozzle and blades jointly is 90%; carry over coefficient is 0·82. Determine

(i) the heat drop in each stage

(ii) degree of reaction

(iii) stage efficiency.

Construct velocity triangles. *20*

(b) With the help of figure, explain the functioning of 'breeder reactor'. Also enumerate the advantages and disadvantages of breeder reactors. *10*

(c) Discuss the site selection for the nuclear power plants based on

(i) population distribution

(ii) land use

(iii) geology

(iv) hydrology. *10*

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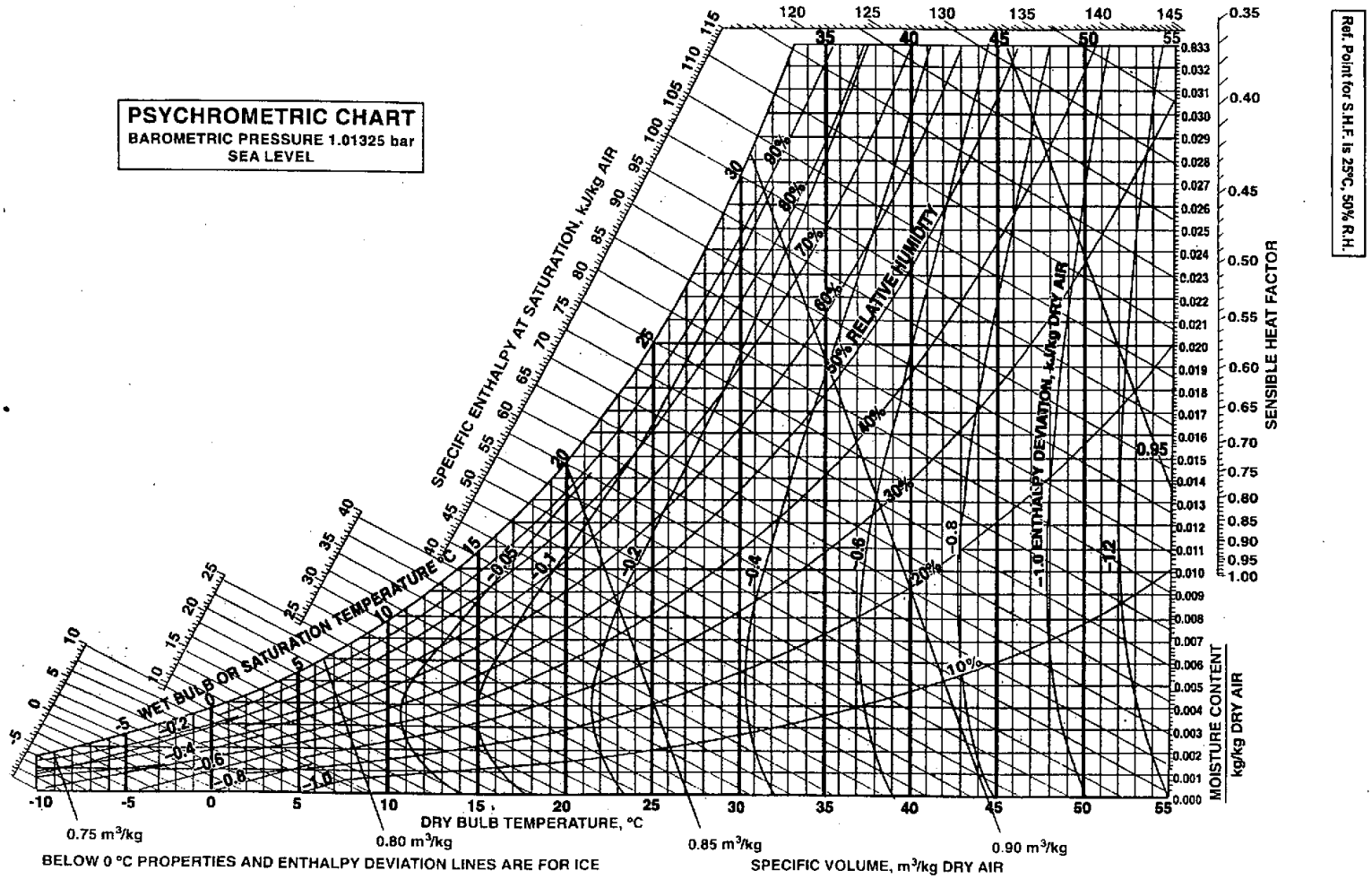

Ref. Point for S.H.F. is 25°C, 50% R.H.