MECHANICAL ENGINEERING Paper I

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 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**.

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SECTION 'A'

1. (a) A disc of mass 5 kg is mounted at the mid-span of a simply supported horizontal shaft having a span of 0.5 in and diameter 10 mm. Modulus of elasticity of the shaft material is 2×10^5 N/mm^2. The centre of gravity of the disc is displaced by 2.5 mm from its geometric centre while fitting on the shaft. The equivalent viscous damping for the system may be taken as 50 N.s/m. The shaft rotates at 740 rpm. Determine

(i) maximum stress on the shaft during its rotation and .

(ii) power required to drive the shaft freely. 10

(b) Discuss the turning moment diagram of a single cylinder 4-stroke engine.

A 4-stroke engine develops 18.5 kW at 250 rpm. The turning moment diagram of this engine may be assumed rectangular for the expansion stroke and compression stroke. The turning moment for expansion stroke is 2.8 times that of the compression stroke. Assume the energy consumed in other strokes in the cycle to be zero. Assuming constant load, determine the moment of inertia of the flywheel required to keep the speed between 247 rpm and 253 rpm. 10

(c) What do you understand by a rotating disc of uniform strength?

A turbine disc is required to have a uniform stress of 150 MPa at a speed of 3200 rpm. The disc is to be of 30 mm thick at the centre. What will be its thickness at a radius of 40 mm?

Assume density of disc material = 7800 kg/m^3. 10

(d) (i) Show how columns will buckle under axial load with four different end conditions. 4

(ii) Calculate the concentration of vacancies in copper at room temperature of 25°C Assume that 20,000 cal. are required to produce a mol of vacancies in copper. The gas constant is 1.987 cal/mol.K. 6

2. (a) In a vertical double-acting steam engine running at 360 rpm, the cylinder diameter is 0.3 m, piston rod diameter is 40 mm and length of connecting rod is 0.7 m. When the crank has moved 120° from top dead centre, the pressure of steam at the covered end is 0.35 N/mm^2 and that at the crank end is 0.03 N/mm^2. If the weight of the reciprocating parts is 500 N and length of stroke is 300 mm, find:

(i) piston effort,

(ii) force on connecting rod, and

(iii) turning moment on the crank shaft for the given crank position. 10

(b) Two shafts A and D are co-axial. They are geared together through an intermediate parallel shaft carrying gears B and C which mesh with the gears on A and D respectively. Gears A and B have a module of 4 mm and C and D have a module of 9 mm. The number of teeth on any wheel is to be not less than 15 and

the speed of D is to be about, but not greater than 1/12 the speed of A and the ratio of each reduction is the same. Find
(i) suitable number of teeth for all the gears,
(ii) actual reduction of speed and
(iii) actual configuration of the system with a dimensional sketch. 10

(c) Discuss how the function of a governor differs from that of the flywheel. Prepare the list of the following according to usage into the three groups:
(i) only flywheel, (ii) only governor, and (iii) both flywheel and governor.
Stationary I. C. engine, automotive I C. engine, gas turbine, steam turbine and hydraulic turbine.
The arms of a Hartnell governor are of equal length. At mid-span of the sleeve, the ball arm is vertical and the radius at which the ball rotates is 8.25 cm when the equilibrium speed neglecting the friction, is 450 rpm. On changing the speed by 1%, the governor is able to overcome friction at this position. The friction force is 30 N at the sleeve and has constant value. The sleeve moves ±1.6 cm from the mean position. The minimum speed of the governor is 428 rpm. The mass of the sleeve is 3.5 kg. Determine the magnitude of the rotating masses of ball and initial compression of the spring. 15

(d) Discuss how multi-cylinder in-line I. C engines are balanced to minimise unbalance, if any.
Investigate the state of primary and secondary balancing of a 4-stroke cycle, 4-cylinder in-line engine with the following firing orders:
(i) 1-2-3-4, and
(ii) 1-2-4-3.
Give your comments. 5

3. (a) Compare the weights of equal lengths of hollow and solid shaft to transmit a given torque for the same maximum shear stress if the inside diameter is 2/3 of the outside diameter. 10

(b) On a simply supported beam (10 m span) a concentrated load (10 kN) and a moment of 40 kN act at a section 7 m from one of the ends. Draw the shear force and bending moment diagrams. Indicate the points of contraflexure if any. 10

(c) How will you distinguish between a thin-walled and a thick walled pressure vessel? What advantage you obtain by wire winding a thin cylinder?
What largest internal pressure can be applied to a cylindrical tank 1.8 meter in diameter and 14 mm wall thickness if the ultimate tensile strength of steel used is 467 MPa and a factor of safety of 7 is desired? 10

(d) At a section in a beam the tensile stress due to bending is 50 N/mm^2 and there is a shear stress of 20 N/mm^2.
Determine from first principles the magnitude and direction of the principal stresses and calculate the maximum shear stress. 10

4. (a) What are superalloys? Give their classifications and typical applications. 10

(b) Explain the characteristics of sintered ceramics. What do you mean by porosity in polycrystaitine ceramic?
Silicon carbide particles are compacted and fired at a high temperature to produce a strong ceramic. The specific gravity of silicon carbide is 3.2 gm/cm^3. The ceramic component was weighed in dry, after soaking in water, and after suspended in water. These values are 360 gm, 385 gm and 224 gm respectively. Calculate apparent porosity and true porosity. 15

(c) What do you mean by stainless steels? Explain three types of stainless steels. 15

SECTION 'B'

5. (a) Discuss in brief, consideration of 'Green Design' and 'Design For Manufacture' approach in manufacturing. 10

(b) Briefly discuss the various stages involved in the process of product development. 10

(c) Define and distinguish between the following characteristics of measuring instruments: Accuracy, drift, rule of 10, resolution, and sensitivity. 10

(d) Given the number, of hours worked and the hourly wage rate, obtain a flow chart to compute the gross salary and net pay of the employee, assuming the tax deduction to be at the rate of 10% of the employee's gross salary if it is less than Rs. 15,000 and at the rate of 20% otherwise. 10

6. (a) How the EDM and ECM processes affect the fatigue strength of machined components? Explain. 10

(b) What is a manufacturing cell? Why it is developed? How the product flow lines may be designed in a manufacturing cell? 10

(c) Explain the mechanism of flank wear of a cutting tool. Plot a flank wear rate curve and indicate the region of' tool failure. 10

(d) An orthogonal machining operation is being carried out under the following conditions:
Depth of cut = 0.1 mm,
chip thickness = 0.2 mm,
width of cut = 5 mm,
rake angle = 10°.
The force components along and normal to the direction of cutting velocity are 500 N and 200 N respectively. Determine
(i) the coefficient of friction between the tool and chip, and
(ii) ultimate shear stress of the workpiece material. 10

7. (a) Discuss Tresca and Von Mises yield criterion for metal forming operations. Also derive tensile and shear yield stress relationships for their approaches. Which of these criterion is more realistic? Why? 10

(b) Discuss the underlying principles involved in designing a good clamping system for jigs and fixtures. 10

(c) A domestic appliance distributor needs to estimate the demand for a certain item on a quarterly basis. This information is important for his annual planning exercise. Data on the demand for the particular item in the last two years is given in the following table:

Data on demand in eight quarters	
Quarter	Demand
Year 1 Ql	80
Q2	90
Q3	65
Q4	110
Year 2 Ql	60
Q2	80
Q3	80
Q4	100

Extract the Trend component of the time series data and use it for predicting the future demand of the item. 20

8. (a) Discuss the difference between operation charts, activity charts and flow process charts. 10

(b) During production a lens manufacturing unit has been examining a lens for scratches. If, in inspectors opinion, there are too many scratches, the lens is "bad" and rejected. Otherwise it is accepted. Using the data given in the following table, construct a control chart for last month's inspected lenses. Sample size is 100. 20

Table of data	
Sample No.	Unit rejected
1	10
2	9

3	8
4	11
5	7
6	12
7	7
8	10
9	13
10	12
11	13
12	14

(c) Solve graphically the L.P.P.

Maximize $Z = 3X_1 + X_2$

subject to restrictions $-2X_1 + X_2 \leq 1$

$X_1 \leq 2$

$X_1 + X_2 \leq 3$

$X_1, X_2 \geq 0$ 10

MECHANICAL ENGINEERING Paper II

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

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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) 0.05 kg of carbon dioxide (molar mass 44 kg/kmol) is compressed from 1 bar, 15°C, until the pressure is 8.3 bar, and the volume is then 0.004 m^3. Calculate the change of entropy. Take C_p for carbon dioxide as 0.88 kJ/kg K, and assume carbon dioxide to be a perfect gas.

Represent the states on pressure-volume and on temperature-entropy diagrams. 10

(b) Petrol used in SI engine is assumed to have a chemical formula C_7H_{16}; Determine:

(i) stoichiometric A/F ratio.

(ii) If 50% excess air is supplied then find the volumetric composition of dry exhaust products.

Air contains 23% of O_2 & 77% of N_2 by Mass. 10

(c) A refrigerator has working temperatures in the evaporator and condenser as - 23°C and 37°C respectively. The environment temperature is 27°C. The required refrigeration temperature is -13°C. What is the maximum COP possible? If the actual COP of the refrigerator is 0.65 of the maximum, calculate the required power input for a refrigerating effect of 5 kW. 10

(d) List the merits and demerits of pulverized coal firing system. Differentiate between pulverized dry-bottom furnace and wet-bottom furnace. 10

2. (a) A test on a single cylinder engine, four stroke having bore 180 mm and stroke 360 mm yielded the following results:

Speed	:	285 rev/min.
Brake Torque	:	393 Nm
IMEP	:	7.2 bar
Fuel consumption	:	3.5 kg/hr
Cooling water flow	:	4.5 kg/ min
Cooling water temp, rise	:	36° C
A/F ratio by mass	:	25
Exhaust gas temp.	:	415° C
Barometric pressure	:	1.013 bar
Room temperature	:	21° C

Fuel has a calorific value 45200 kj/kg and contains 15% by mass of hydrogen.

Determine:
(i) indicated thermal efficiency.
(ii) The volumetric efficiency based on atmospheric conditions.
(iii) Draw up a heat balance in terms of kJ/min explaining clearly the content of such term.

Take R = 0.287 kJ/kgK,
C_V for dry exhaust gases = 1.005 kJ/kgK
C_p for superheated steam = 2.05 kJ/kgK. 15

(b) Consider three fluids with Prandtl numbers of 0.01, 1 and 100 flowing in a circular tube. Calculate the ratio of the L_{th} and L_c.L_{th} is the length required to achieve a fully-developed temperature profile and L_c is the length required to obtain a fully-developed velocity profile. Assume that the flow is laminar and that the heat transfer takes place with a constant wall heat flux boundary condition.
Comment on: (i) the Prandtl numbers given in this problem. Give suitable example corresponding to these Prandtl numbers, (ii) L_{th} and L_c at these Prandtl numbers and justify the same. 10

(c) Why are downcomers fewer in number and bigger in diameter, while risers are more in number and smaller in diameter in a water tube boiler? Describe the working principle of a modern natural circulation boiler. What are the functions of preheater, reheater, economizer and superheaters? Where are these located? 15

3. (a) Discuss the process of combustion in CI engine and also explain various stages of combustion. Discuss the factors that affect, the delay period. 15

(b) (A) What is fouling? What is fouling factor? Is fouling desirable?
(B) Sea water below 50°C is passed through the cooling coils of a large electromagnet. The heat transfer with clean coils is 2000 W/m^{2}K. Calculate the heat transfer coefficient including the effects of fouling. What is the percentage reduction in the value of the heat transfer coefficient? Fouling factor for sea water is 0.0001 m^2 K/W.
(C) In addition to thermal aspects of designing a heat exchanger, list other factors which need careful consideration. Which of these factors influence running cost? What should be the basis for optimising design of a heat exchanger?
2 + 6 + 2 = 10

(c) (i) What are the functions of a condenser in a steam power plant?
How does a cooling tower operat? Define a dry cooling tower. When is it recommended?
(ii) Explain the meaning of draught as applied to boilers. How is it produced by various methods? Write down the specific advantages of balance draught system. 10 + 5

4. (a) A 4 stroke single cylinder diesel engine develops a 36 kW when running at 800 rpm and consumes 240 gms/kWh. The pressure of the air in the cylinder at the beginning of injection and at the end of injection are 40 bar and 60 bar. The injection pressure at the beginning and end of injection are 200 bar and 600 bar respectively.
Determine the diameter of the nozzle if the injection is carried out during 15° rotation of the crank. The ambient pressure and temp, are 1.013 bar and 27°C. C_{df} = 0.6 and ρ_f = 800 kg/m^3. 15

(b) A vapour compression plant uses R134-a and has a suction temperature of -5°C and a condenser saturation temperature of 45°C. The vapour is dry saturated on entering the compressor and there is no undercooling of the condensate. The compression is carried out isentropically in two stages and a flash chamber is employed at an interstage saturation temperature of 15°C. Calculate:
(i) the amount of vapour bled off at the flash chamber;
(ii) the state of the vapour at the inlet to the second stage of compression;
(iii) the refrigerating effect per unit mass of refrigerant in the condenser;
(iv) the work done per unit mass of refrigerant in the condenser;

(v) the coefficient of performance. 15

Properties of R134-a are given below.

Data for R134-a

Saturated Values							Superheat			
t	Sat. Pressure	v_g	h_f	h_g	s_f	s_g	10 K		20 K	
							h	s	h	s
°C	(bar)	m^3/kg	KJ/kg		KJ/kgK		KJ/kg	KJ/kgK	KJ/kg	KJ/kgK
−5	2.4371	0.081	93.46	291.77	0.9760	1.7155	302.18	1.7536	312.05	1.7884
15	4.8734	0.042	120.06	303.38	1.0709	1.7071	314.86	1.7463	325.56	1.7817
45	11.5447	0.017	162.93	319.54	1.2105	1.7028	332.87	1.7440	345.04	1.7804

(c) With the help of a sketch, discuss the working principle of boiling water reactor and explain in brief the function of main elements. 10

SECTION—B

5. (a) Given that

$$C_p = T.\left(\frac{\partial S}{\partial T}\right)_p \text{ and } \quad C_v = T.\left(\frac{\partial S}{\partial T}\right)_v$$

obtain the expressions of

$$\left(\frac{\partial C_p}{\partial P}\right)_T \text{ and } \left(\frac{\partial C_v}{\partial v}\right)_T$$

Using Maxwell's and other relations.

Using the above derived equations, show that C_p and C_V for an ideal gas are functions of temperature only. 10

(b) (i) Discuss the three-way catalytic converter used in S.I. engines. Why isn't a normal three-way catalytic converter, as used with S.I. engines as useful, when used with C.I. engines?

(ii) Discuss main methods used to limit No emissions on a modern automobile.

5 + 5 = 10

(c) A mild steel tank of wall thickness 10 mm contains water at 90°C when the atmospheric temperature is 15°C. The thermal conductivity of mild steel is 50 W/mK and the heat transfer coefficients for the inside and outside of the tank are 2800 and 11 W/m^2 K, respectively. Calculate:

(i) the rate of heat loss per unit area of tank surface.

(ii) the temperature of the outside surface of the tank. 10

(d) Explain stalling and surging phenomenon in compressors with the help of head-discharge curves. 10

6. (a) An automobile has 3.2 liter five cylinder, four stroke cycle diesel engine operating at 2400 rpm. Fuel injection occurs from 20° b TDC to 5° a TDC. The engine has a volumetric efficiency of 0.95 & operates with fuel equivalence ratio of 0.80. Light diesel fuel is used. The pressure is 101 kPa, Temp. 298 K, R = 0.287 kJ/kg K. Calculate

(i) time for one injection.

(ii) fuel f1ow rate through an-injector. 10

(b) (A) Define effective temperature (ET). Does it meet comfort criteria? Justify.

(B) Define Bypass Factor (BF). Illustrate the influence of bypass factor on various parameters. Is it desirable to have high bypass factor? Discuss extreme possible cases.

(C) Discuss evaporative cooling with the help of a schematic diagram and psychrometric chart. Discuss limitations of evaporative cooling.

(D) In an industrial evaporative cooling application with summer outdoor design conditions of 40°C DBT, 27°C WBT; the indoor is to be maintained at a maximum relative humidity of 55%. The room sensible heat is 581.5 kW. All outdoor air must be used. Find the room dry bulb temperature and supply air

quantity as a function of humidifying efficiencies of 80 and 100%. Comment on the DBT in the room and supply air quantity in both these cases.

2 + 2 + 2 + 9 = 15

(c) (A) The incremental fuel costs for two generating units a and b of a power plant are given by the following relations:

$$\frac{dF_A}{dP_A} = 0.06P_A + 11.4$$

$$\frac{dF_B}{dP_B} = 0.07P_B + 10$$

where P is the power in MW and F is the fuel cost in rupees per hour.

(i) Find the economic loading of the two units when the total load to be supplied by the power station is 150 MW.

(ii) Find the net increase in fuel cost per hour if the load is equally shared by the two units.

(B) What are the considerations to be made while selecting the suitable site for a steam and a hydro power plant? 10 + 5

7. (a) (A) You are required to predict performance of a given heat exchanger. What method would you use? Why?

(B) A parallel flow heat exchanger has a hot and a cold water stream running through it. The flow rates are 10 and 25 kg/min and the inlet temperatures are 70°C and 25°C on the hot and the cold side respectively. Calculate the area of the heat exchanger if (i) the individual heat transfer coefficients on both sides are 1600 W/m^{2}K; (ii) effects of fouling can be neglected; and (iii) the exit temperature on the hot side is required to be 50°C.

(C) For the problem in (B) above, calculate the exit temperature of the hot and cold streams in this heat exchanger if the hot water flow rate is doubled to 20 kg/min and it is known that the individual heat transfer coefficients are proportional to the 0.8th power of the flow rates. 1+7+2=10

(b) (A) Illustrate with the help of schematic' of psychrometric chart, determination of apparatus dew point (ADP) using ESHF. Discuss extreme possible cases and measures to be taken to overcome such cases.

(B) A laboratory having an unusually large latent heat gain is required to be air-conditioned. The design conditions and the loads are as under:

Summer outdoor design conditions	:	40° DBT, 27°C WBT
Indoor design conditions	:	25°C DBT, 50% RH
Room Sensible Heat (RSH)	:	34.9 kW
Room Latent Heat (RLH)	:	18.6 kW

The ventilation air requirement is 85 m^3/min. Determine the following:

(i) Ventilation load

(ii) Room Sensible Heat Factor (RSHF) and Effective Sensible Heat Factor (ESHF)

(iii) Apparatus Dew Point (ADP) and amount of reheat for economical design

(iv) Supply air quantity

(v) Condition of air entering and leaving coil and supply air temperature.

(vi) Grand Total Heat.

Assume a suitable bypass factor. Solve this problem using psychrometric chart. 5 + 10 = 15

(c) Explain the influence of ratio of blade speed to steam speed on blade efficiency of a single stage impulse turbine. 15

8. (a) Mention the cycles which have an efficiency equal to that of the Carnot cycle working between given temperature limits T_1 and T_2. Represent these cycles on T-s diagram. Prove for one of the cycles the expression for efficiency of the cycle is the same as that of the Carnot cycle. Comment on the work ratio (net work out divided by gross work output) of the cycle chosen and that of the Carnot cycle. 10

(b) (A) Define log mean temperature difference (LMTD.) Develop expression for LMTD in a parallel-flow heat exchanger. How is this expression modified for counter-flow heat exchanger? Under what situations, LMTD is independent of the flow arrangements — namely: parallel-flow, counter-flow and cross-flow? Give practical examples for such situations.

(B) Steam is condensed on the shell side of a shell-and-tube heat exchanger with the help of cooling water flowing inside the tubes. The entering steam is saturated and at a temperature of 100°C. It leaves as saturated water at the same temperature. The cooling water enters the tubes at 30°C and leaves at 70°C. Calculate the log mean temperature difference (LMTD.) 5 + 5 = 10

(c) A gas turbine power plant consists of a two stage compressor with intercooling and a single stage turbine with a regenerator. Air enters the compressor at 1 bar, 20°C. The maximum temperature of the cycle is limited to 900°C and the maximum pressure ratio is 6. The effectiveness of the regenerator is 0.7. The rate of air flow through the plant is 210 kg/s and the calorific value of fuel used is 40.8 MJ/kg. The isentropic efficiency of both the compressors is 0.82, the isentropic efficiency of the turbine 0.92, the combustion efficiency is 0.95.

Take for air C_p = 1.005 kJ/kg K. and γ = 1.4 and for gases, C_p = 1.08 kJ/kg K and γ = 1.33. Assuming perfect intercooling and neglecting pressure and heat losses, estimate

(i) the air-fuel ratio
(ii) the cycle efficiency
(iii) the power supplied by the plant and
(iv) the specific fuel consumption of the plant and the fuel consumption per hour.

20