MECHANICAL ENGINEERING Paper I

Time Allowed: Three Hours *Maximum Marks: 250*

Question Paper Specific Instructions

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

*There are **EIGHT** questions divided in **TWO SECTIONS** and printed both in **HINDI** and in **ENGLISH** Candidate has to attempt **FIVE** questions in all.*

*Questions no. **1** and **5** are compulsory and out of the remaining, any **THREE** are to be attempted choosing at least **ONE** from each section.*

The number of marks carried by a question I part is indicated against it.

Answers must be written in the medium authorized in the Admission Certificate which must be stated clearly on the cover of this Question-cum-Answer (QCA) Booklet in the space provided. No marks will be given for answers written in a medium other than the authorized one.

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Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself

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

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SECTION A

Q1. (a) Draw a cranked-slider quick return mechanism and explain its principle with figure. 10

(b) Explain the fundamental law of gearing with a neat sketch. 10

(c) A circular punch, 20 mm in diameter, is used to punch a hole through a steel plate 10 mm thick. If the force necessary to drive the punch is 250 kN, determine the maximum shearing stress developed in the plate. 10

(d) A spherical gas container made of steel has 5.4 m outer diameter and wall thickness of 10 mm. Knowing that the internal pressure is 400 kPa, determine the hoop stress and longitudinal stress in the container. 10

(e) What are the advantages of tempering carbon steel? Show with the help of iron-carbon equilibrium diagram, how low, medium and high temperature tempering are done. 10

Q2. (a) Consider a hollow circular shaft whose outside diameter is 0.0762 m and whose inside diameter is equal to one-half the outside diameter. The shaft is subjected to twisting moment of 2259.584 N-m as well as bending moment of 3389.376 N-m. Determine the principal stresses. Also determine the maximum shear stress. 20

(b) For the beam shown in Figure 2(b), write the equations for the shear force and bending moment at any point. Also draw the shear force and bending moment diagrams. 20

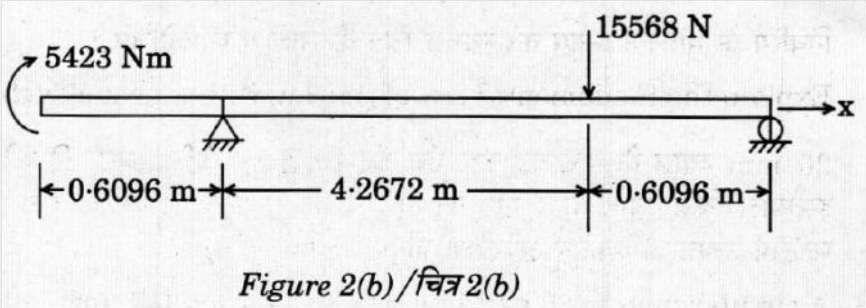

Figure 2(b) /चित्र 2(b)

(c) Find the centroid of the element shown in Figure 2(c). 10

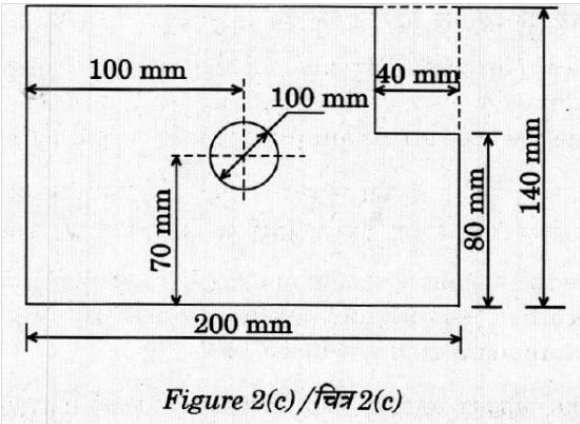

Figure 2(c) /चित्र 2(c)

Q3. (a) An epicyclic gear train consists of a pinion, a wheel of 40 teeth and an annulus with 84 internal teeth concentric with the wheel. The pinion gears with the wheel and the annulus. The arm that carries the axis of the pinion rotates at 100 rpm.

(i) Find the speed of the wheel.

(ii) Find the speed of the annulus, if the wheel is fixed. 20

(b) A machine of mass 20 kg is mounted on springs and dashpot as shown schematically in the Figure 3(b). The total stiffness of the springs is 100 N/cm and the total damping is 1.5 N-sec-cm^{-1}. If the system is initially at rest and a velocity of 10 cm/sec is imparted to the mass, determine

(i) the displacement and velocity of the mass as a function of time,

(ii) the displacement and velocity at the time equal to one second. 20

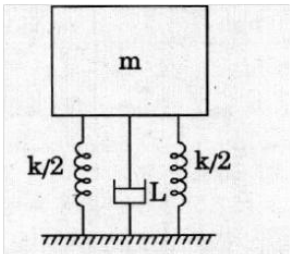

Figure 3(b) /चित्र 3(b)

(c) What is the composition of maraging steel? What are its uses? Give the composition of austenitic stainless steel and state some of its application. 10

Q4. (a) An automobile with the distance between front and rear wheels 3.0 m and height of centre of gravity 300 mm is travelling over a roadway inclined at an angle θ with horizontal. The coefficient of static and dynamic friction are 0.6 and 0.5 respectively. The automobile is a rear wheel drive and has a load of 18 kN. What is the maximum inclination θ_{max} that the automobile can climb at uniform speed? 20

(b) A riveting machine is driven by a constant torque 4 kW motor. Each riveting operation takes 1 second and requires 9000 N-m of energy. A flywheel of mass 130 kg and radius of gyration 0.5 m is fitted to the riveting machine. If the speed of the flywheel is 420 rpm before riveting, find
(i) the fall in the speed of the flywheel after riveting,
(ii) the number of rivets fitted per hour. 20

(c) What are the advantages of annealing steel? Explain the process of annealing with a sketch of Time - Temperature transformation and ending with spheroidizing. 10

SECTION B

Q5. (a) What are the different tool wear causes that are responsible for wearing of tool? Explain crater, flank and wear. 10

(b) There are five jobs each of which must go through machines A, B and C in the order A - B - C. Processing times are as per the following table:

Job i	Processing Time		
	A_i	B_i	C_i
1	8	5	4
2	10	6	9
3	6	2	8
4	7	3	6
5	11	4	5

Determine the sequence for the five jobs that will minimize the elapsed time. 10

(c) Derive the relationship between tensile and shear yield stresses by applying the following: 10
(i) Von-Mises criterion (Maximum distortion energy)
(ii) Tresca criterion

(d) Discuss the advantages and limitations of 'Process Layout'. 10

(e) A 20 mm diameter shaft and bearing are to be assembled with a clearance fit. The tolerance and allowances are as under:
Allowance = 0.002 mm
Tolerance on hole = 0.005 mm
Tolerance on shaft = 0.003 mm
Find the limits of size for the hole and shaft, if
(i) the hole basis system is used,
(ii) the shaft basis system is used.
The tolerances are disposed off unilaterally. 10

Q6. (a) In an orthogonal cutting operation, the tool has a rake angle = 10°. The clip thickness before the cut = 0.5 mm and the cut yields a deformed clip thickness = 1.125 mm.
Calculate
(i) shear plane angle,
(ii) shear strain for the operation.
Derive the formulae that are to be used while finding out the shear plane angle and shear strain. 20

(b) How is plasma arc welding different from tungsten inert gas welding (TIG)? Why is plasma arc welding associated with higher temperatures? With the help of neat sketches, explain transferred and non-transferred plasma arc welding. 20

(c) Briefly explain the different types of jigs. What do you understand by intermediate jig concept? 10

Q7. (a) (i) Derive an expression for Economic Order Quantity (EOQ) when stock replenishment is non-instantaneous (Production Model) with the following assumptions: 10

I. Item is sold and consumed at the constant rate which is known.

II. Set-up cost is constant and does not change with lot size.

III. The increase in inventory is not instantaneous but gradual.

(ii) A contractor undertakes to supply diesel engines to a truck manufacturer at the rate of Rs. 25 per day. Cost of holding a completed engine in stock is Rs. 16/month. Production of engines is undertaken in batches. Each time a new batch is started, a set-up cost of Rs. 10,000 is required irrespective of the number of engines produced. How frequently should the batches be started and what will be the minimum average inventory cost and production time, if the production rate is 40 engines/day?

Assume 300 working days in a year. 10

(b) A dairy firm has three plants located in a State. The daily milk production at each plant is as follow:

Plant 1 : 6 million litres

Plant 2 : 1 million litres

Plant 3 : 10 million litres

Each day, the firm must fulfil the needs of its four distribution centres.

The minimum requirement of each centre is as follows:

Distribution Centre 1 : 7 million litres

Distribution Centre 2 : 5 million litres

Distribution Centre 3 : 3 million litres

Distribution Centre 4 : 2 million litres

Cost (in hundreds of rupees) of shipping one million litres from each plant to each distribution centre is given in the following table:

		Distribution Centre			
		D_1	D_2	D_3	D_4
Plant	P_1	2	3	11	7
	P_2	1	0	6	1
	P_3	5	8	15	9

Find the initial basic feasible solution for minimum total cost by

(i) Least Cost Method, and

(iii) Vogel's Approximation Method. 20

(c) Will Just-In-Time (JIT) work in service requirement as well as it works in production environment? Enlist the applications of JIT in service industry. 10

Q8. (a) Use the dual simplex method to solve the following problem:

Maximize : $z = -2x_1 - 3x_2$

subject to : $x_1 + 3x_2 \geq 2$

$2x_1 - x_2 \leq 10$

$x_1 + x_2 \leq 8$

with x_1 and x_2 non-negative. 20

(b) With the help of a neat schematic sketch explain the electrochemical machining process. Also discuss its applications. 20

(c) Discuss the advantages and limitations of NC manufacturing process. Also enlist the advantages of CNC manufacturing over NC manufacturing process. 10

MECHANICAL ENGINEERING Paper—II

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QUESTION PAPER SPECIFIC INSTRUCTIONS

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SECTION—A

Q. 1(a) Derive the optimum pressure ratio of an ideal gas turbine plant for maximum network. Also, show with the help of T-s diagram that, an optimum pressure ratio exists. 10

Q. 1(b) Consider one-dimensional isentropie flow of a perfect gas. Derive an appropriate expression to show that the shape of the nozzle for supersonic flow is divergent in cross-section. 10

Q. 1(c) A small sphere (of outside diameter = 60 mm) with a surface temperature of 300°C is located at the geometric centre of a large sphere (of inside diameter = 360 mm) with an inner surface temperature of 15°C. Calculate how much of emission from the inner surface of the large sphere is incident upon the outer surface of the small sphere. Assume that both bodies approach black body behaviour. What is the net interchange of heat between the two spheres? 10

Q. 1(d) Steam at atmospheric pressure enters the shell of a surface condenser, in which the water flows through a tube bundle, at the rate of 0.05 kg/s. The inner diameter of the tube is 25 mm. The overall heat transfer coefficient, (U_i) based on the inner diameter is 230W/m^2°C. The inlet and outlet temperatures of water are 15°C and 70°C, respectively. The condensation of steam takes place on the outside surface of the tubes.

Calculate the following:

(i) The effectiveness of the heat exchanger and NTU.

(ii) Length of each tube.

(iii) The rate of steam condensation.

Assume C_p of water = 4-18 kJ/kg°C; h_{fg} = 2257 kJ/kg (latent heat of condensation). 10

Q. 1(e) Propane (C_3H_8) is burned with 100% excess air in an adiabatic burner. Both the fuel and air enter the burner at 25°C and 1 bar. Estimate the maximum temperature that can be attained in the flame. The molar heat capacities of the product gases are as follow:

$C_p^\circ(CO_2) = 19.8 + 7.344 \times 10^{-2}\ T$

$C_p^\circ\ (H_2O) = 32.24 + 1.924 \times 10^{-3}\ T$

$C_p^\circ\ (O_2) = 28.11 - 3.68 \times l0^{-6}\ T$

$C_p^\circ\ (N_2) = 31.15 - 1.357 \times 10^{-2}\ T$

Here C_p° is in J/mol. K and T is in K. Assume standard heat of this reaction as ΔH_{298}° = −2045.5 kJ. 10

Q. 2(a) Explain what do you mean by kinetic energy correction factor. Show that the kinetic energy correction factor for laminar flow through a circular pipe is 2. Further, explain what will happen to the kinetic energy correction factor when the flow is considered to be turbulent. 20

Q. 2(b) A plane wall 90 mm thick (k = 0.18 W/m°C) is insulated on one side while the other side is exposed to environment at 80°C. The rate of heat generation within the wall is 1.3×10^5 W/m^3. If the convective heat transfer coefficient between the wall and the environment, (h) is 520 W/m^2°C, determine the maximum temperature in the wall. Derive the expression used, starting from the steady state one-dimensional heat conduction with heat generation equation. 20

Q. 2(c) Show that the slope of a reversible adiabatic process on a temperature versus pressure diagram, when multiplied by Cp is given by T$v\beta$. 10

Q. 3(a) A centrifugal compressor running at 16,000 rpm takes in air at 17°C and compresses it through a pressure ratio of 4:1 with an isentropic efficiency of 82%. 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 Cp = 1.005 kg/kg.K; γ = 1.4. Also draw the velocity triangles at inlet and impeller exit. 20

Q. 3(b) A nine (9)-cylinder, 4-stroke petrol engine of bore 14.5 cm and stroke 18 cm, has a compression ratio of 7:1 and develops 350 kW at 2000 rpm when running on a mixture of 15% weak. The fuel used has a heating value of 47 MJ/kg and contains 85.2% C and 14.8 H_2. Assuming a volumetric efficiency of 76% at 15°C and 1 bar and mechanical efficiency of 90%, calculate the indicated thermal efficiency of the engine. Given, R = 287 J/kg-K. 20

Q. 3(c) A boiler furnace of 3 m height is made in the shape of a frustum of a cone with the bottom diameter 5 m (d_1) and top diameter 6 m (d_2). The emissivity of both the surfaces is 0.9. The bottom surface is at 1000°C and the top surface is at 500°C. Considering the inclined surface is refractory surface, find (i) the radiation heat

transfer from the bottom to top surface and (ii) the inclined surface temperature. Radiation Shape Factor $F_{1\text{-}2} = 0.4$. 10

Q. 4(a) A 2-stroke motor cycle petrol engine cylinder consists of 15 fins on its outer surface. If the outside and inside diameters of each fin are 200 mm and 100 mm respectively, the average fin surface temperature is 475°C and the atmospheric air temperature is 25°C, calculate the heat transfer rate from the fins for the following cases:

(i) the motor cycle is stationary;

(ii) when the motor cycle is running at a speed of 60 kmph.

The fin may be idealized as a single horizontal plate of the same area, and the significant length may be taken as $L = 0.9\ d_0$, where d_0 is the outer diameter of the fin. Assume d_0 as 200 mm.

The properties of air may be taken as follows:

$k = 4.266 \times 10^{-2}$ W/m°C; $\nu = 40.61 \times 10^{-6}$ m^2/s; Pr = 0.677

For turbulent flow (forced convection) : $Nu \approx 0.036\ (Re)^{0.8}\ (Pr)^{0.33}$

For natural convection :

$Nu = 0.54.\ (Gr.\ Pr)^{1/4}$ if $(Gr.\ Pr) < 10^9$

$Nu = 0.10\ (Gr.\ Pr)^{0.33}$ if $(Gr.\ Pr) > 10^9$. 20

Q. 4(b) A gas turbine operating on actual simple Brayton cycle is to be designed for maximum output. If the maximum and minimum temperatures of the cycle, the efficiencies of compressor and turbine are fixed, derive the expression for optimum actual pressure ratio. What will be the value of optimum pressure ratio for turbine, if the ratio of maximum and minimum temperature is 3 and $\gamma = 2$?

Take efficiencies of turbine and compressor as 0.9 and 0.8 respectively. 20

Q. 4(c) Explain what do you mean by Highest Useful Compression Ratio (HUCR) for S.I. engines and also state its importance. 10

SECTION—B

Q. 5(a) Justify the suitability of thermostatic expansion valve in comparison to automatic expansion valve. 10

Q. 5(b) Explain with a neat sketch, how air charge, air consumption, torque and mechanical efficiency vary with the range of speed in I.C. engines. 10

Q. 5(c) (i) A steam power plant, working on Rankine cycle has constant steam temperature. The condenser pressures are 25, 50 and 75 mm of Hg and inlet steam pressure varies from 20 to 160 bar. Explain with the help of performance curve and reason how the thermal efficiency will vary.

(ii) Which are the factors effecting Nozzle efficiency? 6 + 4

Q. 5(d) Air flows in a circular duct which suddenly contracts in the cross sectional area. Draw the flow sketch and locate the points on the sketch where turbulent flow will occur and calculate the dynamic loss co-efficient. Take the co-efficient of contraction as 0.62. 10

Q. 5(e) What is an Orsat apparatus? Draw a neat diagram of Orsat apparatus and explain its functioning. 10

Q. 6(a) In a drier operating at steady state atmospheric air at 30°C and 101.325 kPa with a relative humidity of 40% is first heated to 110°C at constant pressure. The heated air is then allowed to pass over the material to be dried and the air leaves the drier at

70°C with a relative humidity of 0.5. If it is required to remove 60 kg/min of moisture from the material, determine the mass flow rate of dry air required in kg/min and the rate of heat transfer to the air as it passes through the heating unit. Use $h_g \,^{1bar}_{110°C}$ = 2696.12 kJ/kg. 20

Q. 6(b) The angles at inlet and discharge of the blading of a 50% reaction steam turbine are 35° and 20° respectively. The speed of rotation is 1500 rpm and at a particular stage, the mean ring diameter is 0.67 m, and the steam condition is 1.5 bar, 0.96 dry. Estimate (i) the required height of blading to pass 3.6 kg/s of steam, and (ii) the power developed by the ring.

Assume, at 1.5 bar pressure, v_f = 0.001052 m^3/kg and v_{fg} = 1.15937 m^3/kg. 20

Q. 6(c) What are the functions of condenser in a refrigerating machine? Name different types of condensers. Describe with neat sketch the evaporative condenser. 10

Q. 7(a) A refrigerating machine, rated to produce 40 tons of refrigeration, is used for air conditioning between the operative temperatures of 42° and 6°C of condenser and evaporator respectively. The refrigerant is dry saturated at the end of compressor. Find the capacity of the plant, power and capacities of compressor and condenser.

Properties of refrigerant

Temp. (°C)	Pressure bar	Enthalpy (kJ/kg)		Entropy (kJ/kg-K)		Volume (m^3/kg)
		h_f	h_g	s_f	s_g	
42	1.957	249.7	410.7	1.125	1.6712	0.6975
6	0.5160	—	407.15	1.018	1.687	0.04035
−32	0.0875	—	390.85	0.9178	1.715	0.1665

If the evaporator's temperature is reduced to -32°C, what will be effect on capacity of plant, power and capacities of compressor and condenser? 20

Q. 7(b) Differentiate between normal and abnormal combustion in SI engines. List out the three major knock limited parameters and explain its use in the engine design. 10

Q. 7(c) Dry saturated steam at 5 bar enters a convergent-divergent nozzle at a velocity of 100 m/s. The exit pressure is 1.5 bar. The throat and exit areas are 1280 mm^2 and 1600 mm^2 respectively. Assuming isentropic flow upto the throat and taking the critical pressure ratio as 0.58, estimate the mass flow rate. If the nozzle efficiency is 0.973, determine the exit condition of steam dryness fraction. Show the process on T-s and h-s diagrams. 20

Properties of steam

P bar	Enthalpy (kJ/kg)		Entropy (kJ/kg-K)		Volume (m^3/kg)	
	h_f	h_g	s_f	s_g	v_f	v_g
5.0	640.23	2108.5	1.8607	4.9606	0.00109	0.3708
2.9	556	2168	1.660	5.344	0.00107	0.6253
1.5	467.11	2226.5	1.4336	5.7897	0.00105	1.158

Q. 8(a) In a cogeneration plant, the power load is 5.6 MW and the heating load is 1.163 MW. Steam is generated at 40 bar and 500°C and is expanded isentropically through a turbine to a condenser at 0.06 bar. The heating load is supplied by extracting steam from the turbine at 2.0 bar, which is condensed in the processor device to saturated liquid at 2.0 bar and then pumped back to the boiler. Compute, (i) the steam generation capacity of the boiler in kg/hr, (ii) the heat input to the boiler in kW, (iii)

the fuel burning rate of the boiler in t/h, if a coal of calorific value 25 MJ/kg is burned and the boiler efficiency is 88, (iv) the heat rejected to the condenser (v) the rate of flow of cooling water in the condenser if the temperature rise of water is 6°C. Neglect pump works. Draw the T-s diagram. Properties of steam: At 40 bar 500°C.
v = 0.08643 m^3/kg, h = 3445.3 kJ/kg, s = 7.0901 kJ/kgK.

P bar	Volume (m^3/kg)		Enthalpy (kJ/kg)		Entropy (kJ/kg-K)	
	v_f	v_g	h_f	h_g	s_f	s_g
2.0	0.00106	0.8857	520.72	2712.1	1.5706	7.0878
0.06	0.00101	25.22	149.79	2565.79	0.520	8.335

Q. 8(b) Discuss the lubrication of the following engine parts with the help of neat sketches:

(i) Main bearings
(ii) Cylinder and small end bearing of connecting rod
(iii) Crank and Gudgeon pin. 15

Q. 8(c) Explain with a sketch how heat is absorbed at various stages from feed water to steam generation in water tube boilers. 15