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.*

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

The number of marks carried by a question/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 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.

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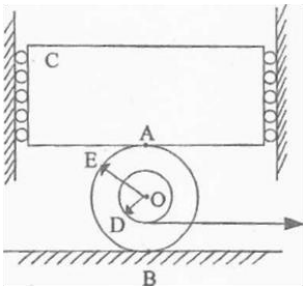
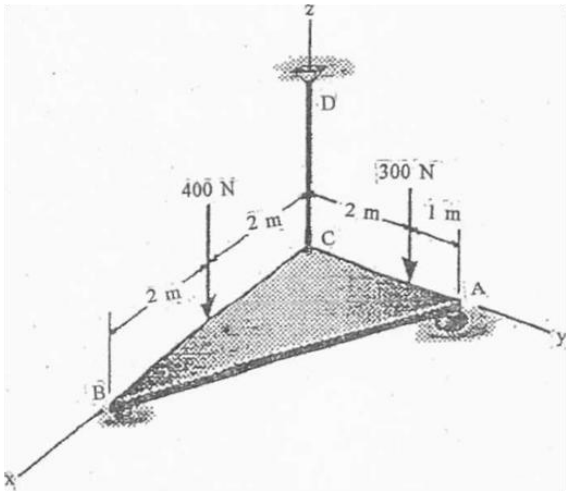
SECTION -A

Q. 1(a) In the Figure shown below, block C has a mass of 50 kg and is confined between two walls by smooth rollers. If the block rests on the top of the 40 kg spool, determine the required coefficient of static friction at A and B so that the spool slips at A and B when the magnitude of applied force P is increased to 300 N. **10**

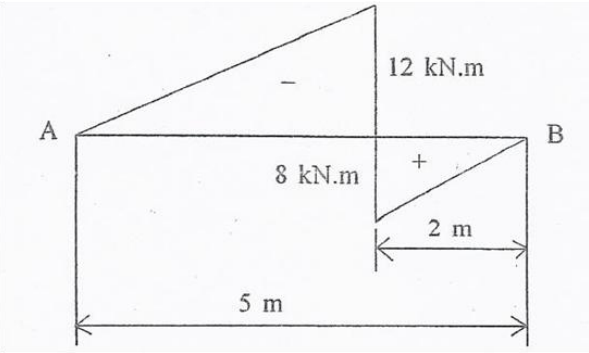


OE = 0.4 m
OD = 0.2 m

Q. 1(b) In the Figure shown, a plate is supported at three positions, A, B and C. A is the ball and socket support, B is the roller support and CD is the cord. Determine the components of reactions at A and B and tension in cord CD. **10**



Q. 1(c) The bending moment diagram for a simply supported beam AB is shown in Fig. below. Sketch the loading diagram and S.F. diagram of the beam. **10**

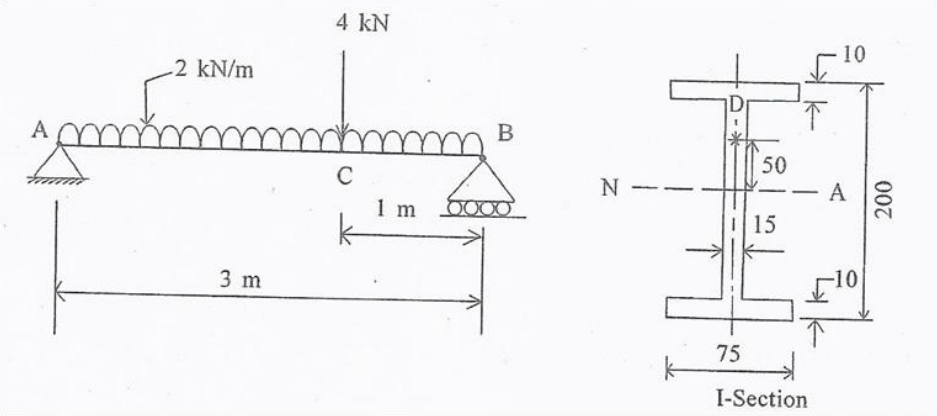


Q. 1(d) Distinguish clearly the function of a flywheel used in I.C. Engines and in mechanical punching presses. For the same power output, why flywheels of multi-cylinder inline engines are relatively smaller than that of single cylinder engine? **10**

Q. 1(e) Differentiate between (i) annealing, and (ii) tempering.
Mark the processes on a TTT diagram and bring out the transformations that take place during the process. **10**

Q. 2(a) A compound pendulum of mass 27 kg is suspended from a pivot, such that the distance of pivot from the mass centre of pendulum is 380 mm. When the pendulum swings about its pivot with small oscillation, the period of oscillation is 1.60 second. If the pendulum is now made to swing with amplitude of 45° on each side of the vertical, find the force exerted on the pivot at the extremity of the swing. **25**

Q. 2(b) A simply supported beam of 3 m span is subjected to loads as shown below. The beam is of I-section and all its dimensions are shown in mm. Determine the principal stresses at point D in the web. This section is located at a distance of 1 m from the right hand support of the beam. **25**



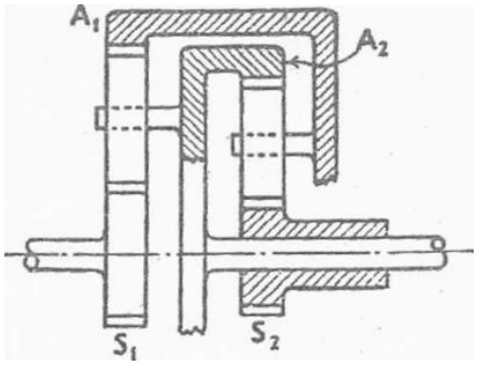
Q. 3(a) In a loaded component principal stresses at a point are 130 MPa and 30 MPa. Using Mohr's stress circle, determine the state of stress at the point with respect to axes *x*' and *y*' which are inclined to σ_1 and σ_2 (principal stress) axes at 30° each in anticlockwise direction. Also determine principal strains at the point. Take E = 200 GPa and G = 80 GPa. **20**

Q. 3(b) The mass of an electric motor is 100 kg. The mass of the armature alone is 30 kg and its centre of gravity lies 0.5 mm from the axis of rotation. The motor is mounted on five springs of negligible damping and the force transmitted to the floor is one-eleventh of the applied force. Assuming mass of the motor is equally distributed

among the five springs, determine the (i) stiffness of each spring (ii) dynamic force transmitted to the floor. The motor is operating at a speed of 1400 rpm. **10**

Q. 3(c) In the epicyclic gear train shown in the Figure, S_1 is the driver, A_2 is connected to output. A_1 and A_2 are annulus gears, and S_1 and S_2 are external gears, in which S_2 is fixed gear. Given the tooth numbers of gears are $S_1 = 40$, $S_2 = 30$, $A_1 = 120$ and $A_2 = 100$, determine the velocity ratio of the co-axial shafts.

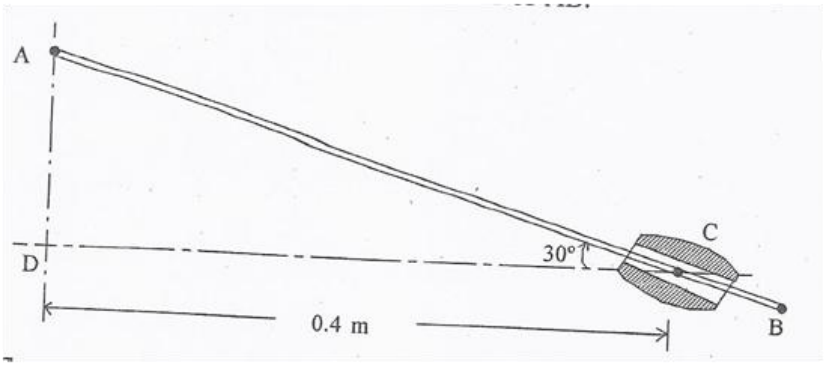
Determine also the magnitude and direction of the torque required to fix S_2, if a torque of 300 N-m is applied in a clockwise direction to S_1. **20**



Q. 4(a) In the figure shown, the end A of a bar AB, is constrained to move along vertical path AD and the bar passes through a swivel bearing pivoted at C. When A has a velocity of 3 m/s towards D and an acceleration of 25 m/s^2 in the opposite direction, determine:

(i) Velocity and acceleration of sliding of bar through the swivel,

(ii) Angular velocity and angular acceleration of AB. **25**



Q. 4(b) What are the desirable properties while selecting a tool material for metal-cutting applications? Compare HSS and ceramic tools with regard to their application in high speed machining. **15**

Q. 4(c) What are composite materials? Enumerate the advantages and limitations of the use of composites as engineering materials. **10**

SECTION—B

Q. 5(a) What is underlying philosophy behind JIT systems? Briefly describe the characteristics of JIT systems. **10**

Q. 5(b) List the basic principles of plant layout. **10**

Q. 5(c) Bars of length 20.05/19.95 mm are in stock. From each, piece of 5.03/4.98 mm are cut. Determine the lengths of the remaining parts. **10**

Q. 5(d) A cup, of 50 mm diameter and 100 mm height, is to be drawn from low carbon steel sheet. Neglecting the influence of thickness and corner radii:

(i) Calculate the blank diameter

(ii) Decide whether it can be drawn in a single draw, if maximum reduction permitted is 40%. **10**

Q. **5(e)** For a machined surface, show macro and micro-irregularities. What are their causes? What are the various measures of surface finish? Explain any three of them. **10**

Q. 6(a) An open loop type NC machine has a stepper motor with a step of 0.9 degree. The lead screw of the machine is of 4 mm pitch.

(i) If the tool has to be moved by 2.87 mm, how many pulses will have to be fed?

(ii) If the motor is rotating at 15 r.p.m., what is the pulse frequency and the feed rate of the machining operation? **10**

Q. 6(b) The process capability of machines manufacturing holes and shafts is ± 0.24 min. The assembly requirements for the hole/shaft, of nominal dimension 20.00 mm, are of clearance between 0.04 and 0.08 mm. Devise the complete scheme (state what it is?) so that satisfactory assemblies are made. **10**

Q. 6(c) Sketch the set-up for spot welding showing details of power input and electrodes

(i) Draw the force/time and current/time diagrams.

(ii) Explain how heating takes place.

(iii) Indicate order of magnitude of current, voltage and time.

(iv) How projection -welding is different from spot welding? **10**

Q. 6(d) The following table gives the monthwise actual demand of units of some product:

Table

Month	March	April	May	June	July	August
Demand (units)	350	440	450	460	495	510

The forecasted demand for the month of March was 400 units.

The firm uses exponential smoothing method with smoothing factor 0.2 to forecast demand.

(i) Calculate the tracking signal for the model.

(ii) Comment on the smoothing factor. **20**

Q. 7(a) An assembly line is to produce 40 microwave ovens an hour. The relevant data for the work elements involved in assembly are given below:

Work element	Time (sec)	Immediate Predecessor(s)
A	20	None
B	55	A
C	25	B
D	40	B
E	05	B
F	35	A
G	14	D, E
H	40	C, F, G

(i) Draw the precedence diagram.

(ii) Design a balanced assembly line.

(iii) Calculate (a) idle time, (b) efficiency, and (c) balance delay.

(iv) What can be the maximum output from this assembly line? **25**

Q. 7(b) How is the domestic kitchen gas cylinder manufactured? State the raw material, its shape and the processes involved. **10**

Q. 7(c) A manufacturer carries stock of an item with an annual demand of 30,000 units. The setup cost (s) and holding cost (h) are not known precisely, though they vary between 100 : 1 and 150 : 1.

(i) Calculate EOQ in both conditions.

(ii) How sensitive is the optimal Q to s/h ratio?

(iii) If s/h doubles or triples, what happens to economic order quantity Q*? **15**

Q. 8 (a) A special screw is being produced on a machine. The diameter of screw is critical and the process is to be controlled. Twelve samples of four screws each are drawn chronologically and inspected. The data is tabulated below:

Sample No.	Screw Diameter (mm)			
	1	2	3	4
1	12.50	12.56	12.51	12.49
2	12.55	12.52	12.51	12.56
3	12.58	12.55	12.54	12.50
4	12.53	12.55	12.56	12.52
5	12.54	12.53	12.51	12.59
6	12.50	12.48	12.53	12.60
7	12.52	12.53	12.51	12.55
8	12.55	12.51	12.58	12.59
9	12.53	12.54	12.51	12.58
10	12.56	12.53	12.55	12.56
11	12.55	12.54	12.54	12.57
12	12.60	12.55	12.54	12.58

The statistical control chart constants for some samples are as under:

No. of observations in sample	Chart for Average Factors for Control Limits			Factor for Central line	Chart for ranges of Factors for Control Limits			
n	A_1	A_2	A_3	d_2	D_1	D_2	D_3	D_4
2	2.121	3.759	1.880	1.128	0.0	3.686	0.0	3.268
3	1.732	2.394	1.023	1.693	0.0	4.358	0.0	2.574
4	1.500	1.880	0.729	2.059	0.0	4.698	0.0	2.282
5	1.342	1.596	0.577	2.326	0.0	4.918	0.0	2.114

Is the process under statistical control? Justify your answer. **20**

Q. 8(b) What is the principle of LBM (Laser Beam Machining)? Draw a sketch and name the salient elements used in LBM. **15**

Q. 8(c) Determine the optimum speed, for minimum cost, for a machining operation. The data is as follows:

Machine hour rate = Rs. 3,000

Cost of tool = Rs. 3,000

Machining time/job = 6 min.

Tool life = 90 min.

Taylor's equation constants c = 100; n = 0.5

Handling time/job = 4 min.

Tool changing time = 9 min. **15**

MECHANICAL ENGINEERING Paper—II

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Section-A

1. (a) Derive an expression for entropy (S) as given below

$$dS = \left(\frac{\delta Q}{T}\right)_{rev}$$

for a closed system undergoing a reversible process. **10**

(b) Write Bernoulli's equation and the conditions for which it is valid. If a fluid ' obeying Bernoulli's equation has elevation, velocity and pressure at a point as 30 m, 50 m/s and 50 bar respectively, calculate the total energy per unit mass of this fluid if its density is 1000 kg/m^3. **10**

(c) What is the effect of Mach number on the compressibility? Derive an expression for pressure coefficient in terms of Mach number. **10**

(d) Explain Wien's displacement law. Assuming sun to be a blackbody with a constant surface temperature of 5780 K, calculate the wavelength at which it will have the maximum spectral emissive power. **10**

(e) In a standard vapour compression refrigeration cycle, the specific enthalpies of refrigerant at the end states of different processes in ascending order are 74.6 kJ/kg, 185.4 kJ/kg and 208.0 kJ/kg. If the mass flow rate of refrigerant is 30 kg/min, calculate power consumption and COP of the cycle. **10**

2. (a) Prove that the cyclic integral of ratio between heat transfer and temperature of any thermodynamic process is less than or equal to zero. **20**

(b) A pipe having 15.4 cm inside diameter and 3.2 m length stands vertically. Another pipe having 10.2 cm inside diameter and 4.8 m length is welded on top of this pipe. Water at 22 °C fills the smaller diameter pipe to a depth of 2.24 m. Above the water is air under an absolute pressure of 242 kPa. Determine the total force on the bottom of the larger diameter pipe. **15**

(c) Hot gases enter the blades of a gas turbine with a velocity of 550 m/s and leave with a velocity of 120 m/s. There is an increase in the enthalpy of the gases in the blade passages to the extent of 5.1 kJ/kg. The rate of gas flow is 98 kg/min. Determine the power produced. **15**

3. (a) Derive an expression for entropy change across a normal shock wave occurring in a nozzle. Show the trend of this entropy change (in the form of a diagram), with respect to the Mach number value before the shock. **15**

(b) Define availability of a closed and steady-flow system. Atmospheric air is compressed steadily from 100 kPa, 27 °C to 500 kPa, 117 °C, by a compressor that is cooled only by atmospheric air. Neglecting kinetic energy changes, determine the minimum work required per kg of air compressed. **15**

(c) In a balanced counterflow heat exchanger, where $\dot{m}_c C_{p,c} = \dot{m}_h C_{p,h}$, show that—

(i) $\Delta T_1 = \Delta T_2 = \Delta T$ at any section;

(ii) the temperature profiles of two fluids are parallel and linear. **20**

4. (a) In a double-pipe heat exchanger, $\dot{m}_h C_{p,h} = 0.5\, \dot{m}_c C_{p,c}$. The inlet temperatures of hot and cold fluids are $T_{h\,i}$ and $T_{c,i}$. Determine an expression, in terms of $T_{h,i}$, $T_{c,i}$ and $T_{h,0}$, for the ratio of area of counterflow heat exchanger to that of parallel-flow heat exchanger, which will give same hot fluid outlet temperature T_{h0}. Also find out the ratio, if $T_{h,i}$ = 150 °C, T_{ci} = 30 °C and $T_{h,0}$ = 90 °C. **25**

(b) A hot plate of 100 cm height and 25 cm wide is exposed to atmospheric air at 25 °C. The surface temperature of the plate is 95 °C. Find the heat loss from both the surfaces of the plate. Also find the change in heat loss if the height of the plate is reduced to 50 cm and the width is increased to 40 cm.

Use the following relations:

$Nu = 0.59\ (Gr.Pr)^{0.25}$ if $Gr.Pr < 10^9$

$= 0.10\ (Gr.Pr)^{0.335}$ if $Gr.Pr > 10^9$

The properties of air are:

ρ = 1-06 kg/m^3;

C_p =1004 J/kg-K

k = 0.029 W/m-K

ν = 18.97 X l0^{-6} m^2 /sec **15**

(c) Do you think that velocity boundary layer and thermal boundary layer depend on Prandtl number? If yes, explain properly. Also explain, with the help of neat sketches, the significance of relative thickness of velocity boundary layer and thermal boundary layer for the following:

(i) Liquid metals

(ii) Oils **10**

SECTION—B

5. (a) Explain Kelvin-Planck and Clausius statements of the second law of thermodynamics and prove that both the statements are equivalent. **10**

(b) How do the following parameters influence knocking in SI engine combustion?

(i) Self-ignition temperature of the fuel

(ii) Air-fuel ratio

(iii) Dilution by residual gas

(iv) Shrouded inlet valve
(v) Combustion chamber design **10**

(c) Hot gases inside a chimney are at 430 °C and the chimney height is 32 metres. The temperature of outside air is 28 °C. The furnace is supplied with 17 kg of air per kg of coal burnt. Calculate—
(i) draught in mm of water;
(ii) draught height in metres of hot gases. **10**

(d) What is the significance of by-pass factor? For a heating coil, derive an expression of by-pass factor. Find the expression for efficiency also for heating coil. **10**

(e) Inner and outer surfaces of a spherical shell are maintained at temperatures T_i and T_0 respectively such that $T_i > T_0$. If inner and outer radii of the shell are r_i and r_0 and its conductivity is k, derive an expression for the rate of heat conduction through the shell. Assume steady state and no heat generation within the shell. **10**

6. (a) In a 4-stroke, 2-cylinder diesel engine, the following data was collected:
Piston stroke = 60 cm
Diameter of the cylinder = 40 cm
Speed of the engine = 250 r.p.m.
Indicated mean effective pressure = 8 bar
Brake power of the engine = 220 kW
Fuel consumption = 80 kg/hr
CV of fuel used = 43000 kJ/kg
Hydrogen content in fuel = 13% and remaining is carbon
Air consumption = 30 kg/min
Cooling water circulated = 90 kg/min
Rise in temperature of cooling water = 38 °C
Piston cooling oil used = 45 kg/min
Rise in temperature of cooling oil = 23 °C
C_p of water = 4.18 kJ/kg-K
C_p of cooling oil = 2.2 kJ/kg-K
C_p of exhaust gases = 1.1 kJ/kg-K
C_p of superheated steam = 2 kJ/kg-K
Latent heat of steam = 2520 kJ/kg
Exhaust gas temperature = 450 °C
Ambient temperature = 27 °C
Find the following quantities per minute:
(i) Heat converted to useful brake power (BP)
(ii) Heat carried away by cooling water
(iii) Heat carried away by cooling oil
(iv) Heat carried away by dry exhaust gases
(v) Heat carried away by steam formed
(vi) Heat supplied by fuel
Draw up also a heat balance sheet on minute basis and percentage basis. **40**

(b) In the pressure crank angle diagram of normal combustion SI engine, show the point of ignition, point of combustion, angle of advance, ignition lag and combustion period. **10**

7. (a) With the help of *T-s* diagrams, differentiate between Carnot and Rankine vapour cycles. State the advantages of Rankine cycle and derive the expression for its thermal efficiency. **15**

(b) A combined cycle power plant operates with mercury and steam cycles. Mercury cycle is superimposed over the steam cycle operating between boiler outlet condition of 40 bar and 400 °C (h = 3215.7 kJ/kg and s_g = 6.713 kJ/kg-K) and condenser temperature of 40 °C. The heat released by mercury condensing at 0.2 bar is used to impart the latent heat of vaporization to the water in steam cycle. Mercury turbine receives mercury as saturated vapour at 10 bar. Calculate the mass of mercury circulated per unit mass of water and the efficiency of this binary cycle. **35**

Properties of saturated mercury and steam are:

	P (bar)	*T* (°C)	*Enthalpy* (kJ/kg)		*Entropy* (kJ/kg-K)		*Sp. vol.* (m^3 / kg)	
			h_f	h_g	s_f	s_g	v_f	v_g
mercury	10	515. 5	72.23	363	0.1478	0.5167	80.5 x 10^{-6}	0.0333
	0.2	277.3	38.35	336.55	0. 0967	0.6385	77.4 x 10^{-6}	1.163
Steam	0.074	40	167. 5	2574.4	0. 572	8.258	0.001	19.546

8. (a) 100 m^3 of air per minute at 15 °C DBT and 80% relative humidity is sensibly heated until its temperature becomes 22 °C. Saturation pressures of water vapour at 15 °C and 22 °C are 0.017 bar and 0.02645 bar respectively. Find heat added to air per minute. Take atmospheric pressure =1.013 bar. **25**

(b) An air refrigerator used for food storage provides 50 tons of refrigeration. The temperature of air entering the compressor is 7 °C and the temperature of air before entering into the expander is 27 °C. Assuming 30% more power is required than theoretical, find (i) actual COP of the cycle and (ii) kW capacity required to run the compressor.

The quantity of air circulated in the system is 100 kg/min. The compression and expansion follow the law $pv^{1.3}$ = constant. Take γ = l.4 and C_p = 1 kJ/kg-°C for air.