MECHANICAL ENGINEERING PAPER I

Time allowed: 3 hours **Maximum marks: 300**

INSTRUCTIONS

Each question is printed both in Hindi and in English.
Answers must be written in the, medium specified in the Admission.
Certificate issued to you, which must be stated clearly on the cover of the answer-book in the space provided for the purpose.
No credit will be given for the answers written in a medium other than that specified in the Admission Certificate.
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.
If any data is considered insufficient, assume suitable value.
Newton may be converted to kg using the equality 1 kilonewton (1 kN) = 100 kg, if found necessary.

Section A

1. Answer any three of the following: (Each answer should not exceed 200 words):

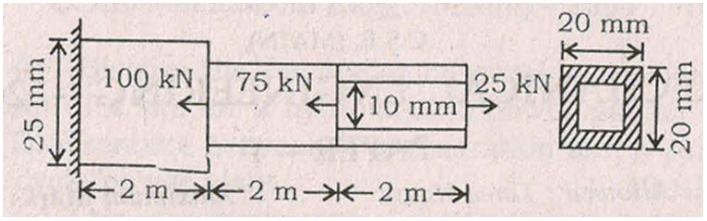
20 x 3 = 60

(a) The turning moment diagram for a quadruple expansion marine engine drawn to the following scales: 1 cm = 15 ton-m and 1 cm = 15°. The areas of the loops above and below the mean turning moment line taken in order are 0.12, 0.34, 0.91, 0.81, 0.15, 0.18, 1.86 and 1.71 cm^2. If the moment of inertia of the propeller and entrained water is 100 ton-m^2 and the mean speed of rotation is 100 r.p.m., what is the value of the coefficient of fluctuation of speed?

(b) A compound tube is made by shrinking a thin steel tube on a thin brass tube. The areas of cross-section of these tubes are A_s and A_b, while the Young's moduli are E_s and $_{Eb}$ respectively. Show that for any tensile load, the extension of the compound tube is equal to that of a single tube of the same length and total cross-sectional area, but having a Young's modulus of

$$\frac{E_s A_s + E_b A_b}{A_s + A_b}$$

(c) A steel rod of square cross-section is loaded as shown in the figure.



Find the section which is subjected to maximum stress, its magnitude and nature. What will be total change in its length? Take E = 200 GPa.

(d) (i) What is a slip system? What is its significance. 10

(ii) Explain the term crystallographic anisotropy. 10

2.(a) An automobile fitted with a spring loaded Hartnell governor, the flyballs of it rotate at 500 r.p.m. having radius of rotation of 7 cm with sleeve in mid-position and balls arms vertical. The length of ball and sleeve arms is same. The maximum sleeve movement is 2 cm with ± 5% variation in speed. The mass of the sleeve is 5 kg and the friction may be assumed to be equivalent of an additional load of 30 N at the sleeve. The effort of

governor is sufficient to overcome the friction of the sleeve caused by 1% change of speed at mid-position. Calculate -

(i) the mass of flyballs;
(ii) the spring rate;
(iii) the initial compression of the spring;
(iv) the governor effort for 1 % change of speed;
(v) the power of governor. 30

(b) The disc of a torsional pendulum has a moment of inertia of 600 kg-cm^2 and is immersed in a viscous fluid. The brass shaft attached to it is of 10 cm diameter and 40 cm long. When the pendulum is vibrating, the observed amplitudes on the same side of the rest position for successive cycles are 9°, 6° and 4°. Find

(i) logarithmic decrement,
(ii) damping torque at unit velocity and
(iii) the periodic time of vibration.

Assume for brass shaft G = 4.4 x 10^{10} N/mm^2. What would be the frequency, if the disc is removed from viscous fluid? 30

3.(a) A hollow column, 400 mm external diameter and 300 mm internal diameter, is hinged at both ends. If the length of column is 5 m, E = 0.75 x 10^5 N/mm^2,factor of safety 5, Rankine's constant 1/1600 and crushing stress 587 N/mm^2, find the safe load the column can carry without buckling. Use Euler's and Rankine formulae. 30

(b) A solid circular shaft running at 110 r.p.m. is used to transmit a power of 30 kW and produces safe stress of 80 N/ mm^2. Find the diameter of shaft. If this shaft is replaced by a hollow shaft having ratio of external diameter to internal diameter of 2, what percentage saving of weight can be achieved, the length and material of the shafts remain same? 30

4.(a) In a tabulated form briefly outline the procedure, general characteristics and two typical applications of carburizing, cyaniding and boronizing processes. 20

(b) Name any four commonly used reinforcing fibres used in plastic composites. What are their properties and applications? 20

(c) What elements are generally alloyed to aluminum? What are their effects? 10

(d) Explain the mechanism of fatigue and creep failures. 10

SECTION-B

5. Answer any three of the following:

(a) In an orthogonal cutting operation, the following data have been observed:
Uncut chip thickness = 0.127 mm
Width of cut = 6.35 mm
Cutting speed = 2 m/s
Rake angle = 10°
Cutting force = 567 N
Thrust force = 227 N
Chip thickness = 0.228 mm
Determine the shear angle, the friction angle, shear stress along the shear plane, and the power for the cutting operation. Also find the chip velocity, shear strain in chip, and the strain rate. 20

(b) With the help of a neat sketch, explain the electro-hydraulic forming process for making tubular parts and list the variables governing the process. What are the main applications of this process? 20

(c) Explain the difference between operation chart, activity chart, and flow process chart. What are their respective areas of application? 20

(d) Explain Johnson's procedure for determining an optimal sequence for processing *n* items on two machines. Determine the optimal sequence of jobs which minimizes the total elapsed time based on the following information (processing time on machines is given in hours and passing is not allowed): 20

Machines	Jobs				
	A	B	C	D	E
M1	5	7	6	9	5
M2	2	1	4	5	3
M3	3	7	5	6	7

6.(a) With a neat sketch, explain the working of ECM machine. How the machining rate is influenced by (i) rate of electrolytic flow, (ii) temperature of electrolyte, and (iii) applied voltage ? What are the main applications of the process? 30

(b) Differentiate between point-to-point and continuous path control systems used in NC machines. What are their respective areas of application? 15

(c) Illustrate the uses of the following preparatory functions:

GOl, G02 and GO3 15

7.(a) Samples of n = 8 items each are taken from a manufacturing process at regular intervals. A quality characteristic is measured, and $\bar{X}$ and R values are calculated for each sample. After 50 samples, we have

$$\sum_{i=1}^{50} \bar{x}_i = 2000; \quad \text{and} \sum_{i=1}^{50} R_i = 250$$

Assume that the quality characteristic is normally distributed.

(i) Compute control limits for the $\bar{X}$ and R control charts.

(ii) All points on both control charts fall between the control limits computed in part (i). What are the natural tolerance limits of the process?

(iii) If the specification limits are 41 ± 5.0, what are your conclusions regarding the ability of the process to produce items within these specifications?

(iv) Assuming that if an item exceeds the upper specification limit it can be reworked, and if it is below the lower specification limit it must be scrapped, what percent scrap and rework is the process producing?

(v) Make suggestions as to how the process performance can be improved. 30

(b) A small electronics company produces pocket calculators and records the demand monthly. The following demand data are for a representative calculator: November 45; December 57; January 60. Using 50 as the first-order exponential smoothing forecast for November, forecast February sales with a smoothing constant of 0.2. Is 0.2 a good choice as a smoothing constant? Comment. 10

(c) A cottage industry produces two types of toys which are sold with a profit margin of Rs. 10 for toy 1 and toy 2 respectively. The assembly cost and packing cost for one unit of type 1 are Rs. 4 and Rs. 5 respectively, and corresponding figures for type 2 are Rs. 5

and Rs. 2. The expenditure on assembly and packing is to be kept strictly within and up to Rs. 100 and Rs. 80 respectively.

Using Simplex Method, calculate the number of toys of each type to be manufactured to get maximum profit. 20

8.(a) What is 'Lay'? Describe with neat sketches and symbols the types of lay produced by different machining processes. 20

(b) What is the function of a clamp? Describe the design and operational factors to be considered for proper and adequate clamping of a workpiece. 20

(c) Write a flow chart to solve the quadratic equation $ax^2 + bx + c = 0$. Write also the corresponding C program. 20

MECHANICAL ENGINEERING PAPER II

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All questions carry equal marks.
Use of Psychometric chart is permitted.

Section A

1. Answer any three of the following (Answers to each of the parts should be in about 200 words only): **20 X 3 = 60**

(a) Using the concept of Second Law of Thermodynamics show that it is impossible to reach absolute zero temperature.

(b) Using Maxwell's relations, show that for a pure substance,

$$Tds = C_p dT - T v \beta dP$$

$$Tds = C_v dT + T\frac{\beta}{K} dv$$

$$Tds = \frac{KC_v}{\beta} dP + \frac{C_p}{\beta v} dv$$

where β is the coefficient of cubical expansion, K is coefficient of compressibility and C_P, C_v are specific heats at constant pressure and constant volume respectively.

(c) Justify in brief, the following statements:
(i) By advancing the spark timing, the possibility to knock in a S.I. engine increases.
(ii) Willans line method for estimating frictional power can be used only in case of unthrottled engines.
(iii) Exhaust hydrocarbon emissions increase with increase in surface to volume ratio of an engine,
(iv) Carbon monoxide emissions are low for fuel lean mixtures.

(d) An I.C. engine fuel has the following composition:
C = 89%, H_2 = 5%, O_2 = 4% and rest N_2.
Determine the chemically correct air-fuel ratio. If 40% excess air is supplied, find the percentage of dry products of combustion by volume.

2.(a) A reversible heat engine operating between thermal reversible reservoir at 800°C and 30°C drives a reversible refrigerator which refrigerates a space at -15°C and delivers heat to a thermal reservoir at 30°C.The heat input to the heat engine is 1900 kJ and there is a net work output from the combined plant (heat engine and refrigerator) of 290 kJ. Determine the heat transfer to the 30° C thermal reservoir. 30

(b) 6 kg of air at 600 Kand50 bar is enclosed in a closed system.
(i) Determine the availability of the system if the surrounding pressure and temperature are 10 bar and 300 K.

(ii) If the air is cooled at constant pressure to the atmospheric condition, determine the availability and effectiveness.

For air take, C_p = 1.005 kJ/kg K, C_v = 0.718 kJ/kg K and R = 0.287 kJ/kg K. 30

3.(a) A six-cylinder, 4-stroke petrol engine has a swept volume of 3.0 liters with a compression ratio of 9.5. Brake output torque is 205 N-m at 3600 r.p.m. Air enters at 85 N/m^2 and 60° C. The mechanical efficiency of the engine is 85% and air-fuel ratio is 15 : 1. The heating value of fuel is 44,000 kJ/kg and the combustion efficiency is 97%. Calculate:

(i) Rate of fuel flow
(ii) Brake thermal efficiency
(iii) Indicated thermal efficiency
(iv) Volumetric efficiency
(v) Brake specific fuel consumption 30

(b) (i) Explain the various stages of combustion in a diesel engine. 15

(ii) Discuss the effect of volatility of gasoline on engine starting, acceleration and vapour lock. 15

4.(a) A 4-stroke petrol engine has a swept volume of 20 liters and is running at 4000 r.p.m. The volumetric efficiency at this speed is 0.75 and the air-fuel ratio is 14 :1. The venturi throat diameter of the carburettor fitted to the engine is 30 mm. Estimate the air velocity at the throat if the discharge coefficient for air is 0.9.The ambient conditions are: pressure = 1.0 bar, temperature = 20° C. Calculate the diameter of the fuel jet if the fuel density is 760 kg/m^3.

For air C_p = 1.005 kj/kg K and R = 287 J/kg K. Assume C_{df} = 1.0. 30

(b) Explain the necessary modifications that have to be made to convert a bus running on diesel fuel to Compressed Natural Gas (CNG). 20

(c) Discuss the advantages of using multi-point fuel injection system in place of conventional carburetor. 10

SECTION-B

5. Answer any three of the following: **20 x 3 = 60**

(a) Illustrate, with neat sketches, the temperature profile for hot and cold fluids as a function of the distance along the path for

(i) parallel flow heat exchangers,
(ii) counter flow heat exchangers,
(iii) condenser and
(iv) gas-heated boiler .

(b) Show that the COP of a cascade refrigeration system is

$$OP = \frac{COP_1 X COP_2}{1 + COP_1 + COP_2}$$

where COP_1, and COP_2 and COP's of low temperature and high temperature side respectively.

(c) An air compressor has eight stages of equal pressure ratio 1.35. The flow rate through the compressor and its overall efficiency are 50kg/s and 82 percent respectively. If the condition of air at entry are 10 bar and 40° C, determine:

(i) the state of air at the compressor exit,
(ii) polytropic or small stage efficiency,

(iii) efficiency of each stage,
(iv) power required to drive the compressor assuming overall efficiency of the drive as 90%.
Take C_p = 1.005 kJ/kg K and γ = 1.4.

(d) A central power station has annual factors as follows:
Load factor = 0.6, Capacity factor = 0.4 and Use factor = 0.45.
The power station has a maximum demand of 15 MW. Determine:
(i) Annual energy production
(ii) Reserve capacity over and above peak load
(iii) Hours per year the plant is not in service.

6.(a) Two large parallel plates at T_1= 1000 K and T_2 = 750 K have emissivities ε_1 = 0.5 and ε_2 = 0.8 respectively. A radiation shield having an emissivity of $\varepsilon_{3\text{-}1}$= 0.12 on one side and an emissivity of $\varepsilon_{3\text{-}2}$= 0.08 on the other side is placed between the plates. Calculate the heat transfer rate by radiation per square meter with and without radiation shield. Take $\sigma = 5.67 \times 10^{-8}$ W/m^{2}K^4. 30

(b) With usual notations, develop an expression for the efficiency of a fin of uniform cross-section when the heat loss from the tip is considered negligible. 30

7.(a) An air conditioning plant is designed to maintain a room at a condition of 20° C dry bulb temperature and specific humidity 0.0079 kg/kg dry air when the outside condition is 30° C dry bulb temperature and 40% saturation. The corresponding heat gains are 18000 W (sensible) and 3600 W (latent). The supply air contains one-third outside air by mass and the supply temperature is to be 15° C dry bulb temperature.
The plant consists of mixing chamber for fresh and re-circulated air, an air washer with chilled spray water with an efficiency of 80%, an after heater battery and a supply fan. Neglecting temperature changes in fan and ducting, calculate:
(i) the mass flow rate of supply air necessary;
(ii) the specific humidity of the supply air;
(iii) the cooling load on the washer;
(iv) the heating load on the after heater. 40

(b) Explain the working principle of Electrostatic Precipitator (ESP). Discuss the factors which affect its efficiency. 20

8.(a) A small compressor has the following data:
Air flow rate = 1.5778 kg/s
Pressure = 1.6
Rotational speed = 54,000 rpm
Efficiency = 85
State of air at entry, P_0, = 1.008 bar ; T_{01} = 300 K C_p for air = 1.009 kJ/kg K.
(i) Calculate the power required to drive this compressor.
(ii) A geometrically similar compressor of three times the size is constructed.
Determine, for this compressor
I. mass flow rate,
II. Pressure ratio,
III. speed and
IV. the power required.

Assume same entry conditions and efficiency for the two compressors and also assume kinematic and dynamic similarities between the two machines. 30

(b) Explain clearly what do you understand by Fanno flow. Show its plot on *h*-*s* diagram and give its characteristics. Air flows in an insulated duct with a Mach number of 0.2. The initial temperature and pressure are 290 K and 2.0 bar respectively. Determine:

(i) the pressure and temperature at a section of the duct where the Mach number is 0.8.

(ii) the distance between these two points if the duct diameter is 10 cm and friction factor is 0.004.

(iii) what will be the maximum length of the duct to avoid choking? 30

Use the following table:

M	P/P*	T/T*	$4fL_{max}/D$
0.2	5.455	1.19	14.533
0.8	1.289	1.064	0.073