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) Two mating gear wheels of module 6 mm have 19 and 47 teeth of 20° obliquity and with addenda of 6 mm. Find the number of pairs of teeth in contact and the angle turned through by the larger wheel while one pair of teeth is in contact.
Explain carefully the advantages obtained by increasing the addendum height for the smaller wheel while maintaining the same working depth. 15 + 5

(b) Write down the expressions for the friction torque in case of flat pivots based on
(i) uniform pressure theory and
(ii) uniform wear theory.
Explain their relevance in design.
A single-plate clutch transmits 25 kW at 900 r.p.m. The maximum pressure intensity between the plates is 85 kN/ m^2. The outer diameter of the plate is 360 mm. Both the sides of the plate are effective and the coefficient of friction is 0.25. Determine –
(1) the inner diameter of the plate;
(2) The axial force to engage the clutch. 5 + 15

(c) (i) What is fatigue? Define fatigue limit and fatigue strength.
(ii) Explain how various factors of design affect the fatigue strength.
(iii) What is cumulative fatigue damage? Explain Miner's hypothesis and bring out the drawbacks of this hypothesis. 5+5+10

(d) (i) What alloys are commonly die-cast? Write the composition, properties and uses of carbide cutting tools.
(ii) Define unit cell. Calculate the linear density of the [100] direction for bcc.
(iii) Draw T-T-T diagram for eutectoid steel. What is a graphite? 20

2.(a) The rotor of a d.c. motor is fixed on the midspan of a 10 mm diameter, 300 mm long steel shaft rotating at 600 r.p.m. and supported on spherical bearings. The mass of the rotor is 10 kg.
(i) Determine the maximum dynamic stress on the shaft for a speed of 0.8 times the critical speed.
(ii) What will happen when the shaft is rotated at 0.95 times the critical speed?

Assume for steel:
$E = 2.2 \times 10^5$ N/mm^2; Yield strength = 220 MPa; Ultimate strength = 420 MPa. 40

(b) Briefly explain the following with examples and nail sketches: 20
(i) Whirling of shafts
(ii) Free, forced and damped vibrations of a single degree of freedom system.

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. 20

(b) A thin cylinder 150 mm internal diameter and 2.5 mm thick has its ends closed by rigid plates and is then filled with water. When an external axial pull of 37 kN is applied to the ends, the water pressure is observed to fall by 0.1 N/mm^2. Determine the value of Poisson's ratio. Assume E = 140000 N/mm^2; K = 2200 N/mm^2. 20

(c) What is the drawback of maximum principal stress theory?
A body is under action of two principal stresses of 40 N/ mm^2 and -70 N/mm^2, and the third principle stress being zero. If the elastic limit in simple tension as well as compression is 200 N/mm^2, find the factor of safety based on the elastic limit according to -
(i) maximum shear stress theory;
(ii) maximum strain energy theory;
(iii) maximum shear strain energy theory.
Take $\mu = 0.3$. 20

4.(a) Define the term proeutectoid cementite. What is the mechanism involved in gas carburizing? What problems exist in nitriding with respect to dimensional stability? What is martempering? What is the function of an energizer in solid carburizing? 30

(b) What factors influence Ms and Mf temperatures? What is temper brittleness and how might it be avoided? What is the process of spherodizing of steel and what is its purpose? 15

(c) Name four types of thermoplastics and write the characteristics and applications of one type. Write in short about fillers and plasticizers. Define metal-matrix composites, their applications and advantages. 15

Section 'B'

5. Answer any three of the following:

(a) What is the fundamental mechanism of chip formation? Some major tool materials are mentioned below:
1. High-speed steel 2. Carbon steel 3. Ceramics 4. Tungsten carbides 5. Cast alloys 6. CBN 7. Single-crystal diamond
Arrange these in terms of wear resistance and toughness, Define the terms adhesion wear and diffusion wear of cutting tool. Write four material properties that affect machinability. 20

(b) Write six advantages of programmable machine tools. Define incremental and absolute system used in NC systems. Discuss the terms roughness, waviness, cutoff and flaws in surface texture measurement. What is the function of machine control unit in NC machines? 20

(c) ABC Ltd. has an order for 500000 parts. These parts can be manufactured either by machining process or by forging process. The costs involved in two methods of manufacturing are as follows:

Process → / Costs ↓	Machining	Forging
Fixed costs (Rs)	15,000	95,000
Variable costs per part (Rs)	6	5

(i) Which of the two methods will be more profit-making for ABC Ltd.?

(ii) Find the minimum order quantity for the forging process to be economical. 20

(d) (i) In statistical quality control, which would be the more sensitive control limits, $\pm 3\sigma$ or $\pm 2\sigma$?

(ii) A manufacturer likes to prepare a statistical quality control chart for the number of mounting bracket hole discrepancies in the power supply chassis of a TV set. Twenty samples of size 200 have been taken and discrepancies are as follows:

Sample number	Number of discrepancies	Sample number	Number of discrepancies
1	11	11	5
2	7	12	7
3	4	13	9
4	1	14	5
5	5	15	17
6	13	16	18
7	6	17	9
8	5	18	5
9	3	19	7
10	0	20	0

Determine the preliminary control limits. Construct the control chart. Plot the twenty samples. Is the process under control? 5+15

6.(a) What are the advantages and disadvantages of d.c. welding machine? What happens during the hold time of a spot weld? Why is the slop control so important in spot welding aluminum?

When would you choose gas welding over arc welding? What do explosive welding and diffusion bonding have in common? 30

(b) Sketch four methods for the manufacture of a pipe. A double-action press for deep drawing a cup is good. Why? Name some advantages of ECM and explain why the gap between electrode and the workpiece is so important in ECM. Name applications and advantages of water-jet cutting. 30

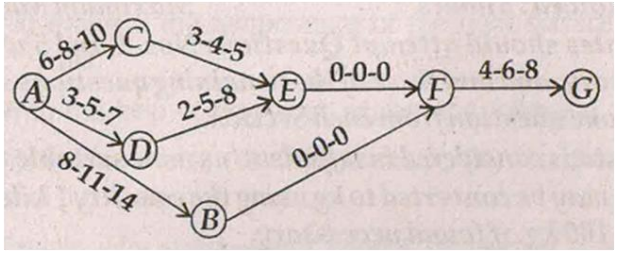
7.(a) (i) What are the sources of error in forecasting?

(ii) With the help of regression analysis, compute the demand for computers when the populations are 36, 45, 50 and 55 millions from the collected data as give below:

Population (in millions)	Number of computers demanded (in thousand)
5	28
7	40
15	65
22	80
27	96

Draw the demand curve using computed value. 5 + 25

(b) The project network for manufacturing a product is given below with seven events (A-G) and eight activities. The estimates of optimistic, most likely and pessimistic times in days are shown as t_0-t_m-t_p, in that order, for each activity:



(i) Determine the slack time for each activity.
(ii) Find the critical path.
(iii) Find the earliest possible project completion time. 30

8.(a) Explain the terms climb milling, gun drills, Morse taper. Sketch a plain milling cutter and indicate the rake angle, clearance angle and tooth face. What are the advantages and limitations of broaching process? Show a standard system of marking grinding wheels with a chart. 30

(b) What is the benefit to the large company of following a JIT policy? 5

(c) The daily demand for a product is normally distributed with a mean of 60 and a standard deviation of 7. The source of supply is reliable and maintains a constant lead time of six days. If the cost of placing the order is Rs 10 and annual holding costs are Rs 0.50 per unit, compute the order quantity and reorder point to satisfy 95% of the customers. Given that 95% corresponds to 1.645 standard deviations. 25

MECHANICAL ENGINEERING PAPER II

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Section A

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

(a) The equation of state of a certain gas is $v = RT/P + K/RT$ (where K is a constant). Show that the change in temperature during throttling (enthalpy before and after remaining the same) of such a gas from an initial pressure P_1 to a final pressure P_2 is given by

$$\frac{T_2^2 - T_1^2}{4K} = \frac{P_1 - P_2}{C_P R}$$

where C_p is assumed constant during the process 1-2.

(b) Consider a large plane wall of thickness L = 0.3 m, thermal conductivity k = 2.5 w/m-K, and surface area A = 12 m^2. The left side of the wall at x = 0 is subjected to a net heat flux of q = 700 w/m^2, while the temperature at that surface is maintained at T_1= 80 °C. Assuming constant thermal conductivity and no heat generation in the wall:

(i) express the differential equation and boundary conditions for steady, one-dimensional heat conduction through the wall

(ii) Obtain a relation for the variation of temperature in the wall by solving the differential equation.

(iii) Evaluate the temperature of the right surface of the wall.

(c) With the help of diagrams, explain the following:

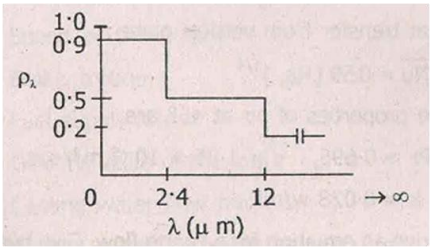
(i) Normal shock,
(ii) Oblique shock,
(iii) Attached shock and
(iv) Detached shock.

Explain why shock-waves cannot develop in a subsonic flow.

(d) Explain the effect of the following factors on the performance of an SI engine:

(i) spark timing
(ii) engine speed
(iii) mass of induced charge
(iv) heat losses.

2.(a) Reflectivity measurements are often used to obtain surface radiation properties. Diffuse spectral reflectivity of a fire brick wall maintained at 500 K is shown below:



The wall is exposed to a bed of coal at 2500 K. Determine the total hemispherical emissivity and emissive power of the fire brick wall. What is the total absorptivity of the wall to the irradiation resulting from emission by coal?

Use the following Plank's radiation functions:

λT (μmK)	F(0-λ)
1200,	0.0025
6,000	0.7393
30,000	0.9912

Assume that the brick wall is opaque and the spectral distribution of irradiation at the brick wall approximates that due to emission from a black body at 2500 K. 40

(b) A 30 cm X 30 cm horizontal duct made of sheet metal carries warm air. The duct is maintained at 65°C and is 10 m long. Heat loss from duct to the ambient air takes place due to free convection only. If the ambient air is at 25°C, calculate the heat loss from the duct. Use the following free convection correlations.

Heat transfer from the upper surface of a horizontal plate:

$Nu = 0.54 (Ra_L)^{1/4}$

Heat transfer from the lower surface of a horizontal plate:

$Nu = 0.27 (Ra_L)^{1/4}$

Heat transfer from vertical plate:

$Nu = 0.59 (Ra_L)^{1/4}$

The properties of air at 45° are

$Pr = 0.695$, $\nu = 1.85 \times 10^{-5}$ m^2/sec, $k = 0.028$ w/mK. 20

3.(a) Derive an equation for a Fanno flow. Give two examples of Fanno flow in thermal system. Show that the upper and lower branches of a Fanno curve represent subsonic and supersonic flows respectively. 25

(b) Air at 1 MPa and 600°C enters a converging nozzle with a velocity of 150 m/s. Determine the mass flow rate through the nozzle for a nozzle throat area of 50 cm2 when the back pressure is (i) 0.7 MPa and (ii) 0.4 MPa.

Given:

$C_p = 1.005$ kJ/kg-K; $K = 1.4$; R = 0.287 kJ/kg-K.

For, $P_t/P_0 = 0.670$, $Ma_t = 0.778$ and $T_t/T_0 = 0.892$

where, subscript *t* represents the properties at the throat. 25

(c) For compressible flows, explain with the help of diagrams, the shapes of nozzles and diffusers in subsonic and supersonic regimes. 10

4.(a) The following set of observations refer to a trial on a Single-cylinder, Four-stroke, Solid injection diesel engine of 200 mm-bore and 400 mm stroke:

Gross mean effective pressure = 6.2 bar

Pumping mean effective pressure = 0.44 bar

Speed of the engine = 262 rpm

Brake torque = 668 N-m
Fuel supply rate = 4.5 kg/hr
Calorific value of the fuel = 52,000 kJ/kg
Cooling water flow rate = 6 kg/min
Cooling water temperature gain = 47°C
Calculate the Indicated Power, Brake Power and Mechanical efficiency of the engine.
Draw up a heat balance sheet for the trial expressing various quantities in kJ/min, if the fuel contains 13.5% H_2 (by mass) and air supply to the engine is 2.71 kg/min at 17°C. The exhaust gases leave the engine at 400°C. The following data may be used:
Mean specific heat of exhaust gases = 1 kJ/kgK
Specific heat of steam = 2.1 kJ/kgK
Latent heat of steam = 2250 kJ/kg
Estimate the heat carried away by steam in exhaust gases. 50

(b) List the advantages and disadvantages of hydrogen as an alternative IC engine fuel. Explain two methods by which hydrogen can be used in CI engine. 10

Section 'B'

5. Answer any THREE of the following:-

(a) How do you classify draught? What are the advantages of the forced draught over the induced draught? What are the limitations of chimney draught? What are the different losses taken into consideration in designing the draught system? 20

(b) Explain with a neat diagram the working of a supercharged boiler. What are its advantages over conventional boilers? Why economizers are essentially used irrespective of the fuel used in boiler furnace? 20

(c) The input-output curve of a 60 MW power station is given by

$$I = 5 \times 10^6 [8 + 8L + 0.4 L2] \text{ kJ/hr.}$$

where, I = Input in kJ/hr; L = Load in MW. Determine:

(i) The heat input per day to the power station if it works for 20 hours at full load and remaining period at no load.

(ii) Saving per kWh of energy produced if the plant works at full load for all 24 hours generating the same amount of energy. 20

(d) A customer complained of poor cooling for an air-conditioning system of 100 TR capacity. The supplier carried out test on condenser which is water cooled and noted power input to the motor. The observations made are as under:
Cooling water flow rate: 10 liter/sec
Inlet water temperature: 30°C
Outlet water temperature: 41.12°C
Power input to motor: 120 kW (94.92 % efficiency)
Determine the actual refrigerating capacity and state whether the cooling capacity is lower, higher or as per specifications. 20

6.(a) Explain with the help of diagrams the difference of working between an open cycle gas turbine and a closed cycle gas turbine. What advantages are derived by using regeneration for open cycle constant pressure gas turbine? Explain properly with the help of diagram. 30

(b) Deduce expressions for optimum pressure ratio for (i) maximum specific output work and (ii) max. cycle efficiency for a Brayton cycle in terms of highest and lowest

temperatures in the cycle and considering isentropic efficiencies of turbo-compressor and turbo-expander. 30

7.(a) Develop an expression for enthalpy of moist air per unit mass of dry air as under:

$$h = 1.005\ t + w(2500 + 1.88\ t)\ \text{kJ/kg}$$

where t is DBT and w is humidity ratio. 15

(b) Discuss the importance of liquid-vapour heat exchanger (LVHE) in the vapour compression refrigeration system. Clearly mention advantages and disadvantages of using such heat exchangers. Represent the cycle on T-s and P-h diagrams and illustrate the influence of LVHE. 15

(c) Moist air enters a chamber at 5°C DBT and 2.5°C WBT at a rate of 90 m^3/min. The barometric pressure is 1.01325 bar. While passing through the chamber, the air absorbs sensible heat at the rate of 40.7 kW and picks up 40 kg/ hr of saturated steam at 110°C. Determine the dry and wet bulb temperatures of leaving air.

Properties of steam are given below:

Enthalpy of saturated steam at 110°C is 2691.3 kJ/kg. 30

8.(a) For a Rankine cycle, using usual notations, show that the thermal efficiency can be expressed as:

$$\eta_{th} = 1 - \frac{h_2 - h_3}{h_1 - h_4}$$

and the second law efficiency can be expressed as:

$$\psi = \eta_{th}\left(\frac{T_H}{T_H - T_0}\right)$$

where T_H is the highest temperature in the entire system and T_0 is the condensation temperature.

(b) "The boiler efficiency is very high as against the thermal efficiency of Rankine cycle." Comment on this statement with the help of laws of thermodynamics and schematic diagrams. 10

(c) A reaction turbine having identical blading delivers dry saturated steam at 3 bar. The velocity of steam is 100 m/sec. The mean blade height is 40 mm and the exit angle of the moving blade is 20°. At the mean radius, the axial flow velocity equals 3/4th of blade speed. For a steam flow rate of 10,000 kg/hr, determine:

(a) the rotor speed in rev/min,
(b) the power output of stage,
(c) the diagram efficiency,
(d) the percentage increase in relative velocity in the moving blade due to expansion in these blades and
(e) The enthalpy drop of steam in the stage.

Specific volume of dry saturated steam at 3 bar is 0.6055 m^3/kg. 35