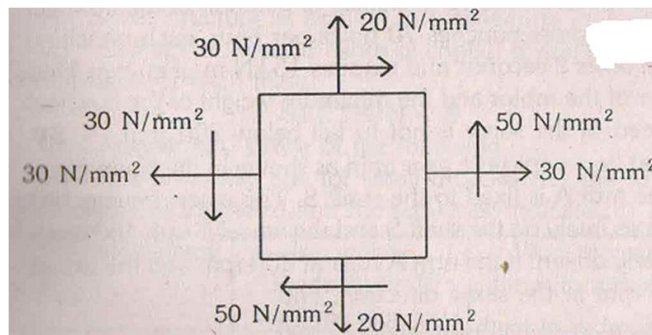## MECHANICAL ENGINEERING PAPER I

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.

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 ball bearings are to be selected for an application in which the radial load is 2 kN during 90 per cent of the time and 8 kN during the remaining 10 percent. The shaft is to rotate at 150 rpm. Determine the minimum value of the basic dynamic load rating for 5000 hours of operation with not more than 10 per cent failures.

(b) The figure given below shows the state of stress at a point namely 30 N/mm^2 tensile in X-direction. 20 N/mm^2 tensile in Y-direction and a shear stress of 50 N/mm^2. Find the location of the principal planes, principal stresses and the maximum shear stress graphically or otherwise.

(c) (i) Derive a formula for increase in volume of a thin metallic sphere when it is subjected to an internal pressure *p*.

(ii) A thin spherical shell of copper has a diameter of 400 mm and a wall thickness of 2 mm and is just full of water at atmospheric pressure. Calculate the volume of water pumped in to raise the inside pressure to 1.5 N/mm^2. The modulus of elasticity for copper is 1 x 10^5 N/mm^2. K (Bulk Modulus) is 2.5 x 10^3 N/mm^2 and Poisson's ratio is 0.25.

(d) What are the defects developed by the components of steel of any machine during heat treatment operation? Give the causes for such defects and explain the remedies taken.

2.(a) A machine of mass 68 kg is mounted on springs of combined stiffness k = 1100 N/mm with an assumed damping factor of 0.2. A piston within the machine of mass 2 kg has

reciprocating motion with a stroke of 75 mm and a speed of 3000 rpm. Assuming the motion of the piston to be simple harmonic, determine

(i)   the amplitude of vibration of the machine
(ii) the phase angle with respect to the existing force and
(iii) the transmissibility and the force transmitted to the foundation. 30
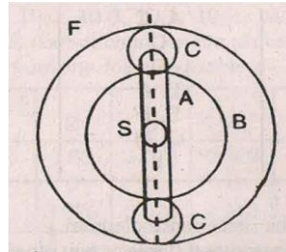
(b) A punching press is derived by a constant torque electric motor. The press is provided with a flywheel that rotates at a maximum speed of 225 rpm. Radius of gyration of the flywheel is 0.5 m. The press punches 70 holes per hour, each punching operation takes 2 seconds and requires 15 kN-m of energy. Find the power of the motor and the minimum weight of the flywheel if the speed of the same is not to fall below 200 rpm.

30

3.(a) In an epicyclic gear train as shown in the figure given below, the arm A is fixed to the shaft S. The wheel having 100 teeth rotates freely on the shaft S and the wheel F with 150 teeth is separately driven. If the arm A runs at 200 rpm and the wheel F at 100 rpm in the same direction, find

(i)   Number of teeth on wheel C and
(ii) Speed of wheel B.   30

(b) A 150 mm diameter shaft supporting a load of 10 kN has a speed of 1500 rpm. The shaft runs in a bearing whose length is 1.5 times the shaft diameter. If the diametric clearance of the bearing is 0.15 mm and the absolute viscosity of the oil at the operating temperature is 11 centi-poise, find the lower wasted in friction. 30

4.(a) Differentiate between:

(i)   Solid solution and Eutectoid and
(ii) Eutectic and Eutectoid

(b) (i) What are ceramics? How are they classified?

(ii) Explain: (a) Silicates (b) Vitreous structure (c) Chain structure and

(d) Sheet structure as applied to engineering materials.   20

(c) Explain the various alloys of copper giving the details of composition of each alloy. 20

SECTION – B

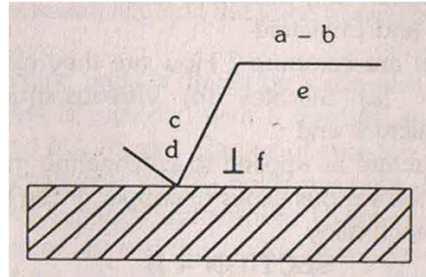**5.** Answer any three of the following:

(a) The assembly line for small tricycles has the following work elements identified and the sequence indicated:

Work element	Immediate Predecessor of the work element	Work element time (in minutes)
A	Nil	5
B	Nil	3
C	B	3
D	A, C	2
E	D	2
F	D	3
G	E, F	5

H	E, F	8
I	G, H	1
J	I	1

For the above:

(i) prepare the precedence diagram.

(ii) using Helgeson and Birnic or any other heuristic method, show a feasible grouping of the work elements and number of work stations, assuming that the cycle time of one assembly is 8minutes.

(iii) calculate the balance-delay for your arrangement. 20

(b) With sketch, show basic surface characteristic of roughness and waviness. What do a, b, c, d, e and f shown in the typical specification illustration given below represent?

Also indicate the values of surface roughness represented by the following triangles:

Δ, ΔΔ, ΔΔΔ, ΔΔΔΔ. 20

(c) A process was set to produce rivets of 10 mm length. The first 32 pieces made by the process were found to have the following lengths (in mm):

9.9, 10.0, 10.0, 9.9, 9.9, 9.9. 10.0. 10.0, 10.1, 10.1, 10.0. 10.0. 9.9 10.1. 10.1. 9.9, 9.9. 10.1. 10.0. 10.1. 10.0, 9.9, 9.9, 9.9, 10.1, 10.0, 10.0, 10.1, 10.0, 10.0, 10.0.

(i) Plot $\bar{X}$ and R control chart for the process, taking data for A_2, D_3 and D_4 from the following table:

No. of observations in the sample	2	3	4	5	6
A_2	1.88	1.023	0.729	0.577	0.483
D_3	0	0	0	0	0
D_4	3.276	2.575	2.282	2.115	2.004

(ii) If the process is not under statistical control, discuss what steps should be taken to make the control chart viable? 20

(d) A ball at the end of a very long pendulum can be assumed to move linearly between two metallic plates at a fixed distance apart. The inner distance between the plates is slightly more than the diameter of the pendulum bob which is spherical, leaving clearance on the left or on the right. If the plates move in simple harmonic motion, the amplitude being very small, the bob may touch the left or the right side plate or it may not touch any, at any instant. If the bob touches the left plate, equation A is governed while if it touches the right plate, equation B is governed. If there is no contact by the bob on any of the plates, then equation C is governed. Write a flow chart in FORTRAN for the motion of the bob. 20

6.(a) (i) What are the advantages of laser beam machining in respect of the following:
Material removal mechanism, energy source, Energy transfer media, potential, current, power, gap and applications. 15

(ii) What is high energy rate forming? Discuss the theory of high energy metal forming. What are the advantages and limitations of high velocity forming? 15

(b) With the help of sketches, show the degrees of freedom, of a work-piece in space, possesses and how nine degrees of these freedoms can be restricted with the help of 6 pins. How are the remaining three degrees of freedom restricted when holding the work-piece for machining? 30

7.(a) In a stop watch time study, the actual readings in minutes, recorded for an element are: 0.05. 0.06. 0.05. 0.05. 0.05. 0.06. 0.06. 0.05. 0.06. 0.06. 0.06. 0.06. 0.05. 0.05. 0.06. and 0.05.

    (i)   Have sufficient number of readings been taken for 95%confidence level and $\pm 5\%$ accuracy?

    (ii)   If the rating is 120%, what would be the normal time for the element?

    (iii) What would be the standard time for the element if the personal needs allowance, fatigue allowance and contingency allowance are 5%, 6% and 5% respectively?

    (iv) What is the purpose of providing contingency allowance? Give two examples. 30

(b) The demand for a newly introduced luxury car has been shown below. The experts forecasted a sale of 100 cars for the month of March. With a smoothing constant of 0.15 and using first order exponential smoothing what is the forecast for the month of August? Also calculate MAD and Bias and give your comments on the same: 30

Month	Actual Demand
March	150
April	200
May	100
June	50
July	150

8.(a) Distinguish between the situations where transportation models and assignment models may be used.

A job shop type machine tool company employs a team of 4 assemblers with varying capabilities. It has received an urgent order to supply 4 assemblies as soon as possible and decides to assign one assembly to each assembler. Assign the assemblies to assemblers so that the total cost is minimised. The following matrix shows the cost of assembly by each assembler in hundreds of rupees. Also calculate the total cost of the 4 assemblies:

	Assembler			
Assembly	5	7	6	8
	7	4	4	9
	3	6	9	6
	8	2	6	1

(b) Name any Five electrodes (tools) materials used in EDM (Electric Discharge Machining). Give the advantages and disadvantages of graphite as a tool material. Also define "flushing" and state its purpose. Describe with sketches, the various types of flushing used in EDM. 30

MECHANICAL ENGINEERING PAPER II

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

INSTRUCTIONS

Each question is printed both in Hindi and in English.

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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.

Use of Psychometric chart is permitted.

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) Distinguish between biogas, producer gas, liquefied petroleum gas (LPG) and compressed natural gas (CNG). Discuss the feasibility of each one of them for use in motor vehicles explaining why you do not consider any of them fit for use in presently vehicles if you so. Consider.

(b) Explain why the exhaust effluent from the tail pipe of a diesel vehicle is black in colour with an obnoxious colour, while it is not so with that from petrol driven vehicles. Which of these exhaust effluent is likely to have higher concentration of oxides of nitrogen and why?

(c) What is meant by free expansion process and how does it differ from throttling process? One kilogram of a gas having pressure P_1 and temperature T_1, is enclosed in an insulated box of volume V_1. It is allowed to expand freely till its volume increases to $V_2 = 2V_1$. Show the process on P-V and T-S diagrams and determine Q, ΔV, W and ΔS for the free expansion process. Comment on the results.

(d) A Carnot Engine is working between temperature limits of T_1 and T_2. Its efficiency can be increased either by increasing the source temperature T_1 or by decreasing the sink temperature T_2.

Determine which is more effective. What are the practical limitations of each of the above methods?

2.(a) 'Knocking in SI Engines is due to auto-ignition of the" end charge" while knocking in CI Engines is due to auto-ignition of the "first charge".

Discuss this statement and tabulate the effect of engine operating and design parameters on the knock intensity in SI and CI engines, giving reasons for the effects indicated by you.   30

(b) What do you understand by the term 'dopes' used in IC Engine practice? Name at least two organic and two metallic dopes. Explain how addition of very small amount of metallic dopes per liter of gasoline completely suppresses knocking in SI engines. What additives are used to increase the Cetane rating of diesel oil?   30

3.(a) Explain what is meant by Higher and Lower Calorific Value of a fuel. Describe with the help of a neat sketch the principle and working of an apparatus used for determining the calorific value of a gaseous fuel.   20

  (b) The following data related to a test trial of a single -cylinder four-stroke gas engine:
  - (i)   Cylinder dia. 24 cm. stroke length 48 cm.
  - (ii)   Compression ratio = 5.9
  - (iii) Net brake load applied at brake wheel having an effective circumference of 3.86 m is 1260 N at average speed of 227r.p.m.
  - (iv)   Number of explosions/minute = 77.
  - (v)   Gas used/mt at 771 mm of mercury and 15°C = 0.217
  - (vi)   Lower calorific value of gas at NTP = 49350 kJ/m^3.
  - (vii) Mean effective pressure from indicator card = 7.5 bar
  - (viii) Weight of Jacket cooling water/mt = 11 kg
  - (ix)   Temperature rise of cooling water = 34.2 °C
  - (x)   Specific heat of water = 4.2 kJ/kg °C

  Estimate (i) mechanical efficiency, (ii) indicated thermal efficiency and (iii) efficiency ratio, and draw a heat balance sheet for the engine assuming that exhaust gases carry away 24% of heat.   40

4.(a) A 200 kg iron block initially at 300 °C is allowed to cool in atmosphere at 30 °C. Determine the reversible work and irreversibility for the cooling process. If this iron block is used to maintain a temperature of 30 °C within an enclosure having outside surrounding temperature of 10 °C, determine the maximum amount of heat that can be supplied to the enclosure space as the iron block cools from 300 °C to 30 °C. For iron C_p = 0.45 kJ/kg-K.   30

  (b) (i) Describe with a neat sketch, the working of a centrifugal compressor. How do pressure and velocity changes take place in impeller and diffuser?

  (ii) Compare the relative merits and demerits of reciprocating, axial and centrifugal compressors.

  (iii) Sketch axial compressor velocity diagrams for a stage. Show that total head pressure rise is given by

$$\frac{P_{03}}{P_{01}} = \left[1 + \frac{u(C_{2w} - C_{1w})}{C_p T_{01}}\right]^{\frac{r}{r-1}}$$

  The notations have the usual meaning.   30

SECTION – B

5. Answer any three of the following parts. (Answer to each part should not exceed 200 words):
  - (a)   Define the terms: capacity ratio, effectiveness and number of transfer units. Derive an expression for effectiveness for a parallel flow concentric heat exchanger in terms of capacity ratio and number of transfer units.
  - (b)   What are the harmful environmental effects of conventional refrigerants? Name any one eco-friendly refrigerant which is being commercially used and discuss its important characteristics.
  - (c)   With reference to air-conditioning practice, explain the difference between human comforts and industrial air-conditioning pointing out the various parameters in each of these applications. Give suitable examples. Sketch and discuss a comfort chart.

(d) Explain the essential distinguishing and relative merits and demerits of Boiling Reactor and Pressurized Water Reactor used in nuclear power plants. How is nuclear waste disposed off?

6.(a) A mixture of air and water vapour at 1.01325 bar.16 °C has dew point of 5 °C. Calculate the relative humidity and specific humidity. 20

(b) A refrigerating plant of 10 kW capacity operates in the quasi ideal vapour compression cycle. The refrigerant is R 134 a. The saturation temperatures in the evaporator and condenser are respectively -20 °C and 40 °C. The plant includes a heat exchanger in which the saturated liquid leaving the condenser is subcooled to 30 °C by the saturated vapour leaving the evaporator. The subcooled liquid is then throttled to - 20 °C before entering the evaporator and the vapour leaving the heat exchanger is compressed isentropically to the condenser pressure. Sketch the schematic diagram and the cycle on p-h and T-s diagrams, numbering the important point. Calculate the mass flow rate of the refrigerant and power to be supplied to the compressor. The mechanical efficiency of the compressor may be assumed 80%. The compressor used by the plant is a single-stage, single acting reciprocating compressor having stroke-diameter ratio of 1.2 and a speed of 240 rev/min. Assuming compressor volumetric efficiency to be 80% determine the diameter and stroke of the compressor.

Properties of refrigerant may be obtained from table below: 35

t	P_S	v_g	Enthalpy (KJ/kg)		Entropy (KJ/kgK)		Specific heat (KJ/kg-K)	
°C	bar	m³/kg	liquid	vapour	liquid	vapour	liquid	vapour
-20	0.3268	0.1474	173.82	386.66	0.9009	1.7417	1.282	0.805
40	10.135	0.0199	256.35	419.58	1.1903	1.7115	1.5	1.12

(c) A central air-conditioning plant is to be installed at Delhi for cooling an office building during the summer season. Give a layout of the plant and explain the various process on a skeleton psychometric chart. 15

7.(a) In a concentric tube heat exchanger, cold water is heated by the heat released by the steam condensation. The water enters the tube at 10 °C and leaves at 50 °C. The steam pressure is maintained at 1.01325 bar (atmospheric). If the length of the tube is increased to 3 times, what would be the outlet temperature of water? Assume overall heat transfer coefficient remains constant for both the cases. Specific heat for water maybe assumed to be 4187 kJ/kg-K. 15

(b) A thin rod of length L has its two ends connected to two reservoirs at temperatures t_1 and t_2 respectively. The rod has the perimeter P and its cross-sectional area A. The rod loses heat to the environment at temperature t_s. The convection coefficient of heat transfer between the rod and the environment is h. Assuming the thermal conductivity of the material of the rod to be constant k, derive expression for (i) the temperature distribution in the rod and (ii) the heat transfer from the rod to the environment. 15

(c) The total emissivity of clean chromium as a function of temperature T K is approximately given as

$$C = 0.38\left(1 - \frac{268}{T}\right)$$

Obtain an expression for the absorptivity of solar radiation as a function of surface temperature. The intensity of solar radiation at earth's surface may be calculated from the following data:

Diameter of sun = 1.39 x 10^6 km
Surface temperature of sun = 600 K.
Distance between sun and earth = 149 x 10^6 km.
Assume sun to behave as a black body. 30

8.(a) Explain the terms: forced draft, induced draft and balanced draft, and discuss their relative merits and demerits. What is the role of a chimney in a boiler? Why no chimney is provided in a locomotive boiler? 20

  (b) An oil fired boiler uses 52 kg/hr of oil having a higher calorific value of 44900 kJ/kg and composition/kg C = 0.847, H_2 = 0.13, S = 0.0125 and generates 635 kg of steam/hr at 10.5 bar pressure from feed water supplied at 338 K. The flue gases having dry gas analysis/unit volume O_2 = 0.043. $_{CO2}$ = 0.124, N_2 = 0.833 and specific heat 1.005 kJ/kg-K, leave the boiler at 635 K. The pressure and temperature of steam after throttling in a throttling calorimeter is 1.15 bar and 398 K respectively. Taking the partial pressure of steam in flue gases as 0.07 bar and the specific heat of superheated steam = 2.1 kJ/kg-K. determine - (i) the equivalent evaporation / kg of fuel;(ii) boiler efficiency.
Draw up a complete heat balance sheet. Take boiler room temperature = 234 K. 40