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.
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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 (l 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) An I-beam has flanges 10 cm wide and 1 cm thick, and the web 12 cm high and 1 cm thick. At a section of this beam acts a bending moment of 1000 kg m and a shear force of 10,000 kg. Find the normal and shear stresses at the following points on the vertical centre line:
  (i) Top of flange
  (ii) In web at the function with flange
  (iii) At the neutral axis

(b) For a two-dimensional stress state —
  (i) Give the expressions specifying the acceptable stress domain according to the generally accepted theories of failure.
  (ii) plot the domains of different theories in σ_1, σ_2 space.

(c) Draw the flow chart and write a computer programme in Fortran for computing standard deviation a of a given set of 100 numbers x_1, x_2,…… x_{100}, where

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=0}^{N}(x_1 - \bar{x})^2}$$

where x_1 is an individual number of a group, $\bar{x}$ is the arithmetic mean of the group of numbers and N is the size of the group of numbers.

(d) For effective vibration isolation of a machine with mass M subjected to harmonic steady force $F_0 \sin\omega t$ mounted on flexible isolators with total stiffness K and viscous damping constant *c*. What are the desirable conditions? Explain with the relevant analysis.

2.(a) In a Hartnell governor where a central spring under initial compression is used for control, under what conditions does the governor become unstable? Also explain the effect of friction between the sleeve and spindle on the performance of the governor. 30

(b) For a 90 V-twin engine system, having two identical cylinders with centre line of each cylinder being inclined at 45° to the vertical, the speed is 2400 r.p.m. The reciprocating

mass per cylinder = 1.5 kg, stroke = 14 cm, length of connecting rod = 28 cm. Find the values of maximum primary and secondary forces, and indicate whether the same can be balanced by suitable means. 30

3.(a) A compound cylinder is made by shrinking an outer tube of outside diameter 200 mm and inside diameter 150mm onto an inner tube, internal diameter 100 mm with a radial interference of 0.2 mm. Both the tubes are made of steel with elastic modulus E = 2 x 10^6 kg/cm^2 and Poisson's ratio $\mu = 0.3$.

Calculate the value of pressure at the interface and values of hoop stress in the two tubes at the interface. Work from the first principles assuming the basic Lame's equations. 30

$$\sigma_r = A - \frac{B}{r^2}; \qquad \sigma_c = A + \frac{B}{r^2}$$

(b) In a slider crank mechanism the crank length is 10 cm and the connecting rod is 40 cm long. The crank rotates in anticlockwise direction at a constant speed of 600 rpm. Find the acceleration of the slider and the angular acceleration of the connecting rod at an instant when the crank is past the inner dead centre by 45º. 30

4.(a) A copper tube 22 mm internal diameter, 30 mm outer diameter and 150 mm long is compressed by a nut lightening over a steel bolt. 20 mm diameter with 1 mm pitch.

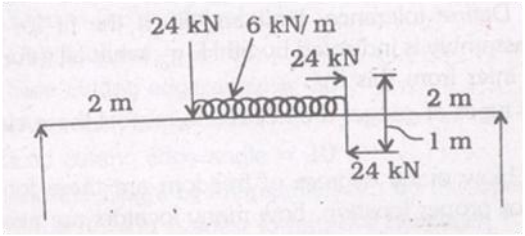
(i) If the nut is tightened by a quarter of a turn beyond the just touching position, determine the stress in the bolt.

(ii) What would be the final stress in the bolt if the temperature of the assembly in (i) is to increase by 10 °C?

Assume: E_{steel} = 2 x 10^6 kg / cm^2; E_{Cu} = 6 x 10^5 kg / cm^2;

α_{steel} =12 x 10^{-6}/°C; α_{Cu} =18 x 10^{-6}/°C. 30

(b) A beam of flexural rigidity 20 MN/m2 is simply supported over a span of 6 m as shown in the figure. It carries a concentrated load of 24 kN, 2m from the left-hand support, and a UDL of 6 kN/m on the central 2 m part. The beam has vertical member welded onto it 2 m from the right-hand support which carry two horizontal loads of 24 kN as shown in the figure. The Distance between these loads is 1 m.



(i) Draw the Bending Moment Diagram for this beam.

(ii) Calculate the vertical deflection of the central point of the beam. 30

SECTION B

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

(a) (i) What all costs result from poor quality of component production?

(ii) How the concept of internal customer and external customer has improved quality manifold?

(iii) How quality productivity, cost, market share, profit and scale of production are related qualitatively?

(iv) What is Demings Award for quality? Has any Indian firm been awarded this recently? 20

(b) What significant information's are provided by T.T.T. diagrams?
Sketch the T.T.T. diagram for high carbon steel with low alloy content. Indicate a cooling line for full hardening. 20

(c) Define tolerance, limit and fit. If the fit for a shaft bearing assembly is indicated by H_{7g6}, what all information's you can infer from this? 50
What types of gauges are needed to inspect these elements? 20

(d) How many degrees of freedom are there for a solid body? For proper location, how many locators are needed for restraining these freedoms? What general design considerations you advocate for proper location without redundancy?
What are diamond locators and where they are used? 20

6.(a) (i) What criteria are generally used to establish tool life while turning with a single-point tool?

(ii) Are tool-life criteria different for material removal consideration and surface quality consideration-if so, why?

(iii) Following data refer to the output of a tool-life experiment:

Cutting speed (meters/minute)	Tool life (minutes)
60	16
90	3

Establish the Taylors tool-life equation.

(iv) What is machinability of a material? What additives improve machinability? 30

(b) (i) Distinguish between Waviness and Roughness of a machined surface.

(ii) How do you define the surface finish under R_1 and R_2 systems?

(iii) In a turning operation following cutting conditions and tool geometry are used:
Cutting speed = 20 meters/minute
Job dia = 50 mm
Feed = 0.3 mm/revolution
Depth of cut = 2 mm
Side cutting edge angle = 30°
(Approach angle = 60°)
End cutting edge angle = 10°
Calculate the height of irregularities left by this operation.

(iv) What do you suggest lo improve the finish?

(v) What is the Ra value in the above? 30

7.(a) Machine shop of a small-scale entrepreneur consists of several general purpose machines, one each. A batch of 5 jobs from a customer arrives on one evening. Setting and processing times in two machines are given below:

Jobs in the Batch	Setting and Processing time (in hours)	
	Machine 1 Milling Machine	Machine 2 Grinding Machine
A	4	2
B	6	10
C	8	4
D	12	8
E	8	12

(i) In what sequence you will suggest to process them to minimize the make span of batch?

(ii) Represent this in the form of a Gantt chart.
(iii) Are there alternative sequences (min make span)?
(iv) What algorithm you have used for this 2-machine system of batch processing and what is the logic of sequencing? 30

(b) Annapurna Freight Company ships freights from 3 warehouses A, B and D to 4 markets R Q, R and S. The transportation costs / truck load in Rs. and the quantity lo be shipped are shown below:

Warehouses	Market or Destinations				Available in Truck loads
	P	Q	R	S	
A	6000	2000	1000	3000	30
B	2000	4000	1000	2000	50
D	3000	6000	5000	1000	45
Required, in Truck Loads	20	25	40	40	

(i) How much should be shipped from each warehouse to each market destination to minimise the transportation cost?
(ii) What is the minimum transportation cost?
(iii) What is the effect of changing CAQ from 2000 to 3000?
(iv) When do you use dummies? 30

8.(a) A plant start up of activities are based on the following sequences:

Activity	Immediate predecessor	Normal time (weeks)	Normal Cost (Rs)	Possible Crash time (weeks)	Crashed Cost (Rs)
A	-	4	1,000	2	1,500
B	-	8	800	2	1,400
C	-	2	400	1	600
D	A	3	800	2	1,200
E	A	5	800	3	1,400
F	C	5	600	1	1,000
G	H, D	6	1,200	2	1,600

(i) Draw the network for this project and label the activities and dummies.
(ii) Identify the critical path.
(iii) What is the normal project completion lime and cost?
(iv) How much H will cost to crash the project completion by 2 weeks; by 3 weeks? (Assume, crashing cost is proportional to time).
(v) What is cost over-run and time over-run and which is worse? 30

(b) A company has 4 salespersons and 4 clients to be visited. Each salesperson can visit only one client because of time constraint. The profit records from previous visits are shown in the table and it is required to maximize the profit by the best assignment:

Clients	Salespersons. Profit (in Rs)			
	A	B	C	D
1	60	120	200	120
2	220	180	150	200
3	120	160	180	150
4	160	80	120	200

(i) Assign the salespersons to appropriate clients to maximize profits.
(ii) What is the maximum profits.
(iii) Instead of profits, if the matrix indicates the distances to be travelled by each salesperson to the respective client and if the distance travelled by each salesperson is to be minimised, what will be the change in your solution procedure? 30

MECHANICAL ENGINEERING PAPER II

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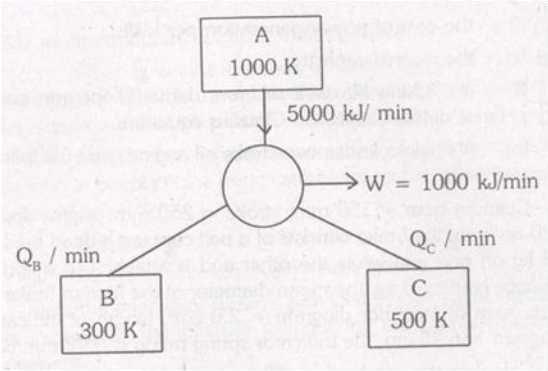
Section A

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) (i) Show that violation of the Kelvin-Planck statement of the Second Law of Thermodynamics implies the violation of Clausius statement. 10

(ii) Figure shows a system that undergoes a reversible cycle during which it exchanges heat with three thermal reservoirs and develops 1000 kJ of work per minute Find the heat interchange Q_H and Q_c. 10



(b) Explain the phenomenon of pre-ignition in SI engines and how it can be detected. How does pre-ignition lead to detonation and vice versa? What are the dangers of pre-ignition? 20

(c) What is Fanno flow? With the help of basic equations explain how Fanno line can be plotted on the h - s diagram. Give the effects of friction on various flow parameters and explain how choking occurs due to friction. 20

(d) A power plant of 220 MW installed capacity has the following particulars:

Capital cost Rs. 40,000 /kW installed

Interest and depreciation 15%

Annual load factor 70%

Annual capacity factor 64%

Annual running charges Rs. 500 X 10^6

Energy consumed by power plant auxiliaries 6%

Calculate:

(i) the cost of power generation per kWh.

(ii) the reserve capacity 20

2.(a) Using Maxwell relation, derive Clapeyron equation. Hence derive Clapeyron-Clausius equation. 20

(b) A single cylinder, two-stroke oil engine gave the following lest data:
Cylinder bore = 150 mm, stroke = 250 mm, engine speed 420 rev/min, the brake consists of a belt carrying a dead load of 48 kg on one end while the other end is attached to a sprig balance reading 3 kg, the mean diameter of the friction brake = 1 m, area of indicator diagram = 2.8 cm2, length of indicator diagram = 6.75 cm, the indicator spring rating is 0.92 mm/bar.
Calculate the mechanical efficiency of the engine. 30

(c) Air is flowing steadily through a well lagged duct. Pressure and temperature of the air are measured at two stations A and B some distance apart along the duct. The readings obtained at these stations are

	Station A	Station B
Pressure	1.3 bar	10 bar
Temperature	50°C	13°C

Deduce the direction of flow in the duct. 10

3.(a) The mass analysis of the petrol used in an engine was 85% C and 15% H_2. The dry exhaust gas analysis showed that the parentage by volume of carbon dioxide was six times that of oxygen and that no carbon-monoxide was present Calculate:
(i) The air-fuel ratio by mass,
(ii) The percentage excess air supplied
Assume air contains 23.2% O_2 by mass or 20.9% O_2 by volume. 30

(b) Discuss the various components of heating and cooling loads in air conditioning giving their classification. 15

(c) What is cetane number of diesel fuel and how is it determined? What is the relationship between cetane number and octane number for petroleum derived fuels? 15

4.(a) Explain, giving reasons, the requirements of air-fuel ratio in petrol engine using carburetor for the following range of operations:
(i) Starting (ii) Idling
(iii) Maximum power (iv) Acceleration
State the additional systems provided in the simple carburetor to achieve the mixture strength for the above modes of operation. 30

(b) What are the causes of smoke formation in a diesel engine? Describe the mechanism of smoke formation. What are the ways of controlling diesel smoke? 15

(c) Steam exists in a power turbine with a dryness fraction of 0.85 and a pressure of 0.1 bar and is condensed to a saturated liquid. The lowest available temperature is 21°C. What fraction of heat rejected to the condenser is available energy? 15

SECTION B

5. Answer any three of the following parts (Answer to each part should not exceed 200 words):

(a) What are the essential properties of a good refrigerant? What refrigerants are used and what factors are considered in selecting a refrigerant for (i) Ice production factory and (ii) Domestic refrigerators?
What are the recent trends in refrigerants to avoid ozone depletion in the stratosphere? 20

(b) Using dimensional analysis, derive an expression for the Nusselt number in terms of Prandtl and Grashof numbers for free convection heat transfer system. 20

(c) Hot air at a temperature of 80° C is flowing through a steel pipe of 10 cm diameter. The pipe is covered with two layers of different insulating materials of thickness 6 cm and 3 cm. Their corresponding thermal conductivities are 0.23 and 0.37 W/m K respectively. The inside and outside heat transfer coefficients are 60 and 10 W/m^2K. The atmospheric temperature is 27°C. Find the rate of heat loss from a 60 m length of pipe. Neglect resistance of steel pipe. 20

(d) Discuss with a diagram the design and off-design performance of a convergent-divergent nozzle, explaining clearly the terms 'over-expanding' and 'under-expanding'. 20

6.(a) Give a schematic diagram of a modern large capacity high pressure boiler and discuss its special features. What is the advantage of providing both convective and radiative superheaters in the boiler plant? 20

(b) A counterflow heat exchanger of heat transfer area of 16.7 m2 is to cool oil (C_{ph} = 2000 J/kgs) with water (C_{pc} = 4170 J/kgs). The oil enters at $t_{h,in}$ = 100°C and m_h = 2.0 kg/sec while the water enters at $t_{c,in}$ = 20°C and m_c = 0.48 kg/s. The overall heat transfer coefficient is U = 300 W/m^2°C. Calculate the exit temperature of water $t_{c,out}$ and the total heat transfer rate Q. 40

7.(a) (i) Discuss the considerations for the selection of sites for thermal, nuclear and hydel power plants. 10

(ii) What do you understand by base load plant and peak load plant and what is the criteria for their selection? 10

(b) An ammonia vapour compression refrigeration plant has two stages of compression and one evaporator. After leaving the condenser at 11.666 bar as saturated liquid without under-cooling it passes the first throttle valve from which it emerges at 4.975 bar to enter a flash chamber. The liquid from flash chamber is then throttled lo 2.909 bar and passes to the evaporator while the dry saturated vapour is passed to a receiver connecting the LP and H.P cylinders. Determine:

(i) the amount of vapour bled off at the flash chamber.

(ii) the coefficient of performance.

Properties of ammonia:

Pressure	Temp.	Enthalpy		Entropy		C_p
bar	°C	kJ/kg		kJ/kgK		kJ/kgK
		h_f	h_g	s_f	s_g	
11.665	30	332.9	1467. 9	1.2028	4 9805	2.956
4.975	4	199.6	1447.6	0.7815	5.2852	
2909	- 10	135.2	1432.0	0.5440	5.4730	

8.(a) A centrifugal compressor running at 18000 rev/min takes in air at 25°C and compresses it through a pressure ratio of 4.0 with an isentropic efficiency of 80%. Guide vanes at inlet give the air an angle of pre-whirl of 20° to the axial direction. The mean diameter of impeller eye is 225 mm. The absolute air velocity at inlet is 130 m/s. At exit the blades are radially inclined. If the slip factor is 0.90, calculate the impeller tip diameter. 30

(b) At a particular stage of a reaction turbine the mean blade speed b 140 m/s and the steam is at a pressure of 20 bar with temperature of 250ºC. Fixed and moving blades at this stage have inlet angles 30º and exit angles 20º. The stage efficiency is 80% Determine:

(i) the specific enthalpy drop across the stage in kJ/kg.

(ii) the drum diameter and blade height of the blade height is one twelfth of the drum diameter and the steam flow is 120 kg/s.

(iii) the percentage increase in relative velocity across the bladings as a result of the pressure drop across the blading. 30