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.

Section A

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

20 x 3 = 60

(a) A 15 mm diameter shaft rotates in long fixed bearings 60 cm apart. A rotor of mass 20 kg is mounted at the mid span. The mass centre of the rotor is 0.5 mm from the shaft axis. If the bending stress in the shaft is not to exceed 120 MPa, find the range of speed over which the shaft must not run. Take modulus of elasticity for the shaft material as 200 GN/m^2.

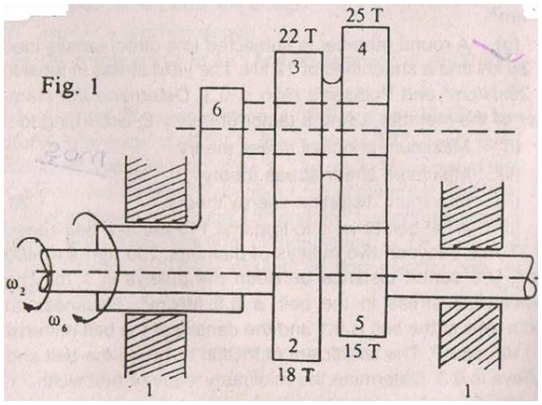
(b) A round member is subjected to a direct tensile load of 20 kN and a shear load of 12 kN. The yield stress in tension is $25kN/cm^2$ and Poisson's ratio is 0.3. Determine the diameter of the member, using a factor of safety 2, according to:
  (i) Maximum principal stress theory
  (ii) Maximum shear stress theory
  (iii) Maximum distortion energy theory.

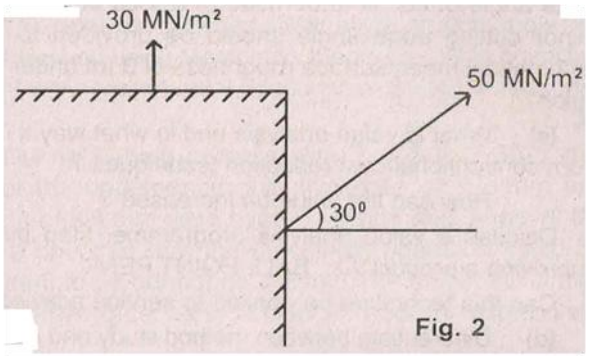
(c) A flat belt drive is to transmit 110 kW at a belt speed 25 m/s between two pulleys of diameter 250 mm and 400 mm. The centre distance between the pulleys is 1 m. The permissible stress in the belt is 8.5 MN/m^2. Thickness to width ratio of the belt is 0.1 and the density of the belt material 1100 kg/m^3. The coefficient of friction between the belt and pulleys is 0.3. Determine the minimum required belt width.
What would be the necessary installation force between the pulley bearings and the force when full power is being transmitted?

(d) Give composition and application of following:-
(i) Stellite (ii) Phosphor Bronze
(iii) Muntz Metal (iv) Alnico.

2.(a) A press has to punch 30 holes per minute and the motor delivers 1.5 kW to the press uniformly. If the actual punching of each hole is accomplished during 30° of crank rotation of the punching machine and the fluctuation of speed is not to exceed ±10%, determine the minimum moment of inertia of the flywheel which is directly mounted on the crankshaft. Neglect the intertie of the rest of the system. 30

(b) Fig. 1 shows a planetary gear train that has two inputs ω_2 and ω_6; Sun gear 2 rotates at 500 r.p.m. and the arm 6 rotates at 750 r.p.m. both clockwise as viewed from left. Determine the speed and direction of rotation of the output gear 5. 30





3.(a) At a point in a material under stress, the intensity of the resultant stress on a certain plane is 50 MN/m^2 (tensile) inclined at 30° to the normal of that plane. (Refer fig. 2) The stress on a plane at right angles to this plane has a normal tensile component of intensity of 30MN/m^2. Find

(i) the resultant stress on the second plane

(ii) The principal planes and stresses

(iii) Maximum shear stress and the plane on which it occurs. 30

(b) A simply supported beam of length 'L' carries a concentrated load W at a distance '*a*' from one and '*b*' from the other ($a > b$). Find the position and magnitude of the maximum deflection and show that the position is always within L/13 approximately from the centre of the beam. 30

4.(a) State: (i) Gibbs phase rule and lever rule

(ii) Isomorphous system

(iii) Pertiectic reaction in steel. 15

(b) Explain:

(i) Strain Aging (ii) Eutectoid steel; (iii) Dead Mild steel. 15

(c) What is TTT diagram for steel? How is it used in designing heat treatment cycle for steels? 15

(d) Differentiate among pearlite, ferrite, martensite and austenite. 15

SECTION B

5. Answer any THREE of the following:-

(a) List the criterion for tool life evaluation for HSS or ceramic tool and sintered carbide tool. Show the variables used in figures. 20

(b) A turning tool with sharp corner and a major cutting edge angle of 60° is to be used at a feed of 0.05 mm. What minor cutting edge angle should be provided to obtain an arithmetical mean surface roughness of 3 μn under ideal condition? 20

(c) What is value analysis and in what way it is different from conventional cost reduction techniques? How can the value be increased? Discuss a value analysis programme, step by step, for improving a product viz. "BALL POINT PEN". Can this technique be applied to service activates? 20

(d) Differentiate between method study and motion analysis. How are they used in job design? The elemental times (in minutes) for 4 cycles of an operation using a time measuring device are presented below:

ELEMENTS	CYCLE TIME IN MINUTES			
	C1	C2	C3	C4
1	3.0	3.0	2.6	2.8
2	5.2	5.4	4.8	5.2

3	6.6	6.4	6.8	6.8
4	2.4	2.4	2.2	2.4
5	1.02	1.02	1.04	0.96

Calculate standard time for the operation, if:

(i) Elements 2 and 4 are machine dependent.

(ii) For other elements, the operator is rated at 110%.

(iii) Total allowances are 15% of the normal time. 20

6.(a) (i) For small feeds, the apparent shear strength of a material increases with decreases in underformed chip thickness. Why?

(ii) The relation between shear angle, friction angle and rake angle derived using Merchant's theory are not in quantities agreement with experimental relationship. State the reasons. 30

(b) During turning process with 7-U-6-6-8-30-1 mm (ASA) tool the undeformed chip thickness of 0.2 mm and width of cut of 2.5 mm were used. The side rake angle of the tool was a chosen that the machining operation could be approximated to be orthogonal cutting. The tangential cutting force and thrust force were 1177 N and 560 N respectively.

Calculate:

(i) The side rake angle

(ii) Coefficient of friction at the rake face.

(iii) The dynamic shear strength of the work material. 30

7.(a) A hole and shaft have a basic size of 30 mm and are to have a clearance fit with maximum clearance of 0.04 mm and a minimum clearance of 0.02 mm. The hole tolerance is to be 1.5 times the shaft clearance. Determine limits for both hole and shaft using:

(i) a hole basis system

(ii) a shaft basis system. 30

(b) Sun Ray Transport Corporation ((SRTC) ships truck loads of grain from 3 godowns to 4 mills. The supply (in truck loads) and the demand (also in truck loads) together with the unit transportation cost per truck load on different routes are given in the adjoining table. Cost of transportation is given in the north-eastern corner in 100's of rupees:

		MILLS				
		A	B	C	D	SUPPLY
	P	10	2	20	11	15
GODOWNS	Q	12	7	9	20	25
	R	4	14	16	18	10
DEMAND		5	15	15	15	

(i) What is north-west corner rule?

(ii) How do you check for degeneracy?

(iii) Design the quantity to be transported from each godowns to different mills, with the objective of cost minimisation of transporting. Develop this using Vogel's approximation (or penalty rating) method (VAM).

(iv) How do you check for optimality of the solution? 30

8.(a) What do you understand by inspection of attributes and inspection of variables? In which case the sample size (for the same confidence level) is more and why?

Weight of pineapple cans with fruit and juice is measured in kg from a continuous production run. Every day a sample of 4 cans are picked up at random and weighed. The data so collected are given in the following table. Plot the $\bar{X}$ and R charts with their control limits.

What is your observation of behavior? What suggestions you wish to make for a proper control of the process?

Day	Weight Of Can With Fruit And Juice, kg			
	1	2	3	4
Day-1	1.20	1.24	1.25	1.25
Day-2	1.24	1.28	1.28	1.14
Day-3	1.10	1.20	1.26	1.26
Day-4	1.18	0.98	1.18	1.16

Constant:

A for control limits of $\bar{X}$ = 0.729

B for control limits of R = 2.282. 30

(b) A plant manufactures two products A and B, using three inputs, labour, material R and material S. To make one unit of product A, it requires 6 kg of R and 7.5 kg of S, and 9 person-hours of labour. To make one unit of B it requires 12 kg f R and 4.5 kg of S and 6 person-hours of labour. The demands for the products are such that the plant can sell as much of each of the product as it can produce. It earns a profit of Rs. 30 per unit of A and Rs.40 per unit of B. However only 900 kg of R and 675 kg of S and 1200 person-hours of labour are available each day.

(i) Formulate the plant's strategy as a linear program to maximise the profit.

(ii) Indicate the feasible region in a graphical representation of the problem.

(iii) Solve the problem graphically by finding the optimum operating point. What is the maximum profit? 30

MECHANICAL ENGINEERING PAPER II

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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) A solar- powered refrigeration system is run by heat transfer Q_H from solar collector at temperature 400 K and rejects heat Q_A at 300 K. It receives heat Q_C from cold space at 200 K. Assuming the cycle to be reversible, and using 1st law of thermodynamics and Clausius inequality, find the ratio Q_C / Q_H.

(b) Calculate the decrease in available energy when 25 kg of water at 97°C is mixed with 35 kg of water at 47°C, the pressure being constant and temperature of surrounding is 25°C. Specific heat of water is C_p = 4.2 kJ/kg-K.

(c) Describe various stages of combustion in C.I. engine by illustrating on pressure-crank angle diagram. Discuss the effect of following operating variables on the first stage of combustion;
  (i) ignition advance
  (ii) compression ratio
  (iii) speed

(d) The brake thermal efficiency of a diesel engine is 30%. If the air to fuel ratio by weight is 20 and the calorific value of fuel is 41800 kJ/kg, find brake mean effective pressure at S.T.P. (15°C and 760 mm of Hg).

2.(a) Air at 17°C and 1.1 bar occupies 0.05 m3. The air is first heated at constant volume until the pressure is 4.4 bar and then cooled at constant pressure back to original temperature. Calculate
  (i) the net heat transfer to or from the air and
  (ii) the net entropy change.
  Given that for air C_p = 1.005 and C_v = 0.718 kJ/kg-K. 30

(b) Two reversible heat engines A and B are arranged in series. Heat engine A rejects heat directly to B. Engine A receives 300 kJ of heat at a temperature of 427°C from a high temperature source while engine B rejects heat to a cold sink at 7°C. If the work output of A is two times that of B, find (i) intermediate temperature between A and B, (ii) efficiency of each engine, (iii) heat rejected by engine A and received by engine B and (iv) heat rejected to the sink. 30

3.(a) A six cylinder, four stroke petrol engine with a bore of 120 mm and stroke of 180 mm under test, is supplied petrol of composition: C = 82% and H_2 = 18% by mass. The Orsat gas analysis indicated that CO_2 = 12%, O_2 = 4% and N_2 = 84% by volume. Determine (i) that air-fuel ratio and (ii) the percentage of excess air.

Also calculate the volumetric efficiency of engine based on intake conditions when the mass flow rate of petrol 32 kg/min at 1600 RPM. Intake conditions are 1 bar and 17°C. Consider the density of petrol vapour to be 3.5 times that of air at same temperature and pressure. Air contains 23% oxygen by mass. 30

(b) The venturi of a sample carburetor has a throat diameter of 20 mm and the fuel orifice has a diameter of 1.12 mm. The level of petrol surface in the float chamber is 6.0 mm below the throat venturi. Coefficient of discharge for venturi and fuel orifice are 0.85 and 0.78 respectively. Specific gravity of petrol is 0.75. Calculate (i) the air-fuel ratio for a pressure drop of 0.08 bar, (ii) petrol consumption in kg/hr and (iii) the critical air velocity. The intake conditions are 1.0 bar and 17°C. For air C_p = 1.005 and C_v = 0.718 kJ/kg-K. 30

4.(a) An eight cylinder automobile engine of 80 mm diameter and 90 mm stroke with a compression ratio of 7, is tested at 4000 RPM on a dynamometer of 600 mm arm length. During a ten minutes test period at a dynamometer scale reading of 450 N, 4.8 kg of gasoline having a calorific value of 45000 kJ/kg was burnt and air at 27°C and 1.0 bar was supplied to the carburetor at the rate of 6.6 kg/min. Find (i) the brake power delivered, (ii) the brake mean effective pressure, (iii) the brake specific fuel consumption, (iv) brake thermal efficiency, (v) the volumetric efficiency and (vi) the air-fuel ratio. 40

(b) A salesman reports that he has a steam turbine that delivers 3 MW. The steam enters the turbine at 6.0 bas, 260°C and leaves the turbine at 0.15 bar and the required rate of steam flow is 12000 kg/hr.

(i) Find the maximum power output of turbine to justify his claim.

(ii) Also, verify his claim if the steam flow rate is 20,000 kg/hr. 20

SECTION B

5. Answer any three of the following parts (Answer to each part should not exceed 200 words): **20 X 3 = 60**

(a) Show that the effectiveness of a parallel flow heat exchanger is given by

$$\varepsilon = \frac{1 - exp\left\{-NTU\left(1 + \frac{C_{min}}{C_{max}}\right)\right\}}{1 + \frac{C_{min}}{C_{max}}}$$

(b) Define Reynolds number, Prandtl number, Stanton number and Nusselt number, and give their physical significance. What is meant by fully developed flow in a pipe? Illustrate it with the help of a figure. State the parameters upon which the entrance length depends.

(c) What is the role of a cooling tower in a power plant? What is meant by range and approach and what purpose does the fill serve in a cooling tower?

(d) Discuss the trends in the design of modern power plant boilers. Explain the zones of heat transfer and location of evaporators, superheaters and reheater.

6.(a) Calculate the number of tubes required for a single pass steam condenser of 2.5 m length to handle 20000 hg/hr Of dry saturated steam at 60°C. The cooling water enters

the tubes at 20°C and leaves at 30°C. The tubes are of 25 mm outside diameter and 22.5 mm inside diameter. The thermal conductivity of tube material is 100 W/m-K. The water velocity is 1.5 m/s. Assume that the steam side film coefficient is 4500 W/m^2-K. For water use,

$$Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$$

The properties of water at 25 °C are:

ρ = 996.95 kg/m^3, C_p = 4178 J/kg-K; k = 60.78 x 10^{-2} W/m-K, ν = 0.9055 x 10^{-6} m^2/s, Pr = 6.22, h_{fg} (at 60°C) = 2358.5 kJ/kg. 40

(b) A small hemispherical oven is built of two insulating materials. The inner layer is of fire brick, 125 mm thick and outer layer of 85% magnesia, 40 mm thick. The inner surface of the oven is at 800°C and the heat transfer coefficient for the outer surface is 10 W/m^2-K. The room temperature is 20°C. Calculate the heat loss through hemisphere is the inside radius is 0.6 m. The thermal conductivities of fire brick and 85% magnesia are 0.31 and 0.05 W/m-K respectively. Also, calculate the temperature at contact between insulating materials and at the outer surface. 20

7.(a) In a refrigeration system of 10 TR cooling capacity using CHCIF2, the evaporator and condenser temperatures are -10°C and 45°C respectively. Properties of CHCIF2 at saturation are:

Temperature	Sp. Volume	Enthalpy		Entropy	
	m^3/kg	kJ/kg		kJ/kg-K	
°C	v_g	h_f	h_g	s_f	s_g
-10	0.0654	34.25	247.37	0.1374	0.9473
45	0.0133	101.76	261.95	0.3662	0.8697

Consider standard vapour compression cycle with inlet to compressor as saturated vapour and inlet to expansion valve as saturated liquid. Assume that vapour may be treated as perfect gas in desuperheating process with average specific heat of 0.9335 kJ/kg-K. Show the cycle on T-*s* and *p-h* diagrams. Find:

(i) compressor outlet temperature and enthalpy,
(ii) mass flow rate of refrigerant,
(iii) work requirement,
(iv) condenser heat rejection,
(v) COP and
(vi) swept volume of compressor in m^3/s assuming 100% volumetric efficiency. 30

(b) In an air-conditioning system 30 m3/min of fresh outdoor air is introduced at 43°C dry-bulb temperature and 30% relative humidity. The remaining air is re-circulated from the room maintained at 25°C dry-bulb temperature and 50% RH. The by-pass factor of the cooling coil is 0.15 and apparatus dew point is 11.8°C. RSH = 100 kW and RLH = 15 kW. Determine (i) humidity ratios for outdoor and room condition, (ii) OASH and OALH, (iii) ERSH and ERLH, (iv) supply air temperature, (v) supply air volume flow rate using ERSH and (vi) temperature at inlet to cooling coil by assuming the density of outdoor air and re-circulated air to be the same.

Given that saturation pressures of water at 25° C and 43° C are 3.1693 kPa and 8.6495 kPa respectively. Show that process on psychometric chart schematically. Standard atmospheric pressure = 1.01325 bar. 30

8.(a) Discuss the effect of pre-whirl on the performance of centrifugal compressors.

A single sided centrifugal air compressor delivers 1800 kg of air per minute. The air enters the eye of the impeller axially at total pressure of 100 kPa and total temperature of 290 K. The overall diameter of the impeller is 700 mm and it rotates at 1600 RPM. The slip factor is 0.9 and work input factor is 1.1. Isentropic efficiency is 85%. Calculate (i) power required by the compressor, (ii) pressure coefficient and (iii) total pressure it delivery. 30

(b) Derive an expression for the blade efficiency of a single row impulse steam turbine assuming equiangular blades in terms of nozzle angle α_1 blade velocity coefficient K and blade speed ratio. If $\alpha_1 = 20°$ and K = 0.9, what is the maximum blade efficiency and corresponding blade angles?

If the blade efficiency is 85% of the maximum value, what are the possible blade speed ratios for the same nozzle angle α_1, blade velocity coefficient, K and equiangular blades? Also, find the corresponding blade angles. 30