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 considered insufficient, assume suitable value.
Newton may be converted into 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) Explain the term 'whirling speed' or 'critical speed' of a shaft. Show that the whirling speed for a rotating shaft is the same as the frequency of natural transverse vibration.

(b) Distinguish clearly between the functions of a cam and an eccentric. What are the considerations which govern the choice of profile of a profile of a cam? To what extent can these considerations be satisfied?

(c) Explain the terms (i) variation in tractive effort (ii) swaying couple (iii) hammer blow as applied to locomotive balancing. Derive expressions for these for a two cylinder locomotive having cranks 90° apart.

(d) Explain what you understand by Gyroscopic Stabilisation. Illustrate with the help of a sketch how this is carried out in ships. Obtain a relation between the Gyroscopic stabilisation if the waves be sinusoidal.

2.(a) A cantilever beam of length l and uniform flexural rigidity EI is subjected to continuously distributed externally supplied moment of intensity m kg-cm per cm of length of the beam. Using the area-moment method, show that the deflection of the free end of the beam is $\delta = ml^3/3EI$, and explain why this is the same deflection as that obtained for the case of a concentrated force $p = m$ applied at the end of the beam. 20

(b) Using the Castigliano theorem, calculate the vertical deflection δ at the middle of a simply supported beam which carries a uniformly distributed load of intensity w over the full span. The flexural rigidity EI of the beam is constant and only strain energy of bending is to considered. 20

(c) A wire of diameter d is wound round a cylinder of diameter D. Determine the bending stress produced on the cross-section of the wire. Hence or otherwise find the minimum radius to which a 1 cm diameter circular rod of high tensile steel can be bent without undergoing permanent deformation. Take yield stress = 17000 kg/ cm^2 and E = 2 X 106 kg/cm^2. What is the magnitude of BM necessary for this? 20

3.(a) In a slider-crank engine mechanism when the crank angle is θ from the inner dead centre position , the gas pressure P is suddenly applied on the piston. The mechanism

was initially at rest. Show that the angular acceleration (α) of the crank at the instant when pressure is applied will be given by the relation

$$\alpha = \frac{PAr\sin(\theta+\varphi)}{J_r\cos\varphi + \frac{W_{rec}}{g}r^2\left[\sin\theta + \frac{\lambda}{2}\sin 2\theta\right]\sin(\theta+\varphi)}$$

where A = cross-sectional area of the piston,

r = crank length $\lambda = r/l$,

l = length of connecting rod;

φ = angle made by connecting rod with the line of stroke at this instant

W_{rec} = weight of the reciprocating parts

J_r = moment of inertia of the crank about the axis of rotation. 18

(b) A mechanism for recording the distance covered by the bicycle is as follows: There is a fixed annular wheel A of 22 teeth and another annular wheel B of 23 teeth which rotates loosely on the axis of A. An arm, driven by the bicycle wheel through gearing not described also revolves freely on the axis of A and carries on a pin at its extremity two wheels C and D, which are integral with one another. The wheel C has 19 teeth and meshes with A and the wheel D with 20 teeth meshes with B. The diameter of the bicycle wheel is 70 cm. What must be the velocity ratio between the bicycle wheel and the arm, if B makes one revolution per 1.6 kilometers covered? 24

(c) A machine punching 3.8 cm diameter holes in a 3.2 cm thick plate, does 60 kg-m of work per square cm of sheared area. The punch has a stroke of 10.2 cm and punches 6 holes per minute. The maximum speed of the flywheel at its radius of gyration is 27.5 m/sec. Find the weight of the flywheel so that its speed at the same radius does not fall below 24.5 m/sec. Also determine the horse-power of the motor driving this machine. 18

4.(a) A twin cylinder uncouple locomotive has its cylinders 60 cm apart and balanced weights are 60° apart, the plans being symmetrically placed about the centre line. For each cylinder the revolving masses are 300 kg at crank pin radius of 32 cm and reciprocating part 285 kg. All the revolving and 2/3rd of the reciprocating masses are balanced. The driving wheels are 1.8 m diameter. When the engine runs 60 km per hour find (i) the swaying couple (ii) the variation in tractive effort and (iii) the hammer blow. 20

(b) A cam having a lift of 1 cm operates the suction valve of a four-stroke SI engine. The least radius of the cam is 2 cm and nose radius is 0.25 cm. The crank angle for the engine when suction valve opens is 4° after t.d.c. and it is 50° after b.d.c. when the suction valve closes. The crank shaft speed is 2000 r.p.m. The cam is of circular type with circular nose and flanks. It is integral with cam shaft and operates a flat faced follower. Estimate (i) the maximum velocity of the value (ii) the maximum acceleration and retardation of the valve (iii) the minimum force to be exerted by the spring to overcome inertia of the valve parts which weigh 200 gm. 30

(c) In a Hooke's joint prove that if the angle between shafts is small, the total fluctuation of velocity ratio varies as the square of the shaft angle. 10

Section-B

5. Answer any three of the following (each answer should not exceed 200 words): **20 x 3 = 60**

(a) What is meant by machinability and how is it expressed? How do you interpret the mechanicability of metal on the basis of chip formation?

(b) Enumerate the reasons responsible for development of newer machining methods. Describe the principle of ultrasonic machining and give its specific application.

(c) What are the essential elements of a jig and fixture for milling? Explain the functions of each element with the help of sketches. What are the materials for each element?

(d) Distinguish between transportation model and assignment model. Indicate a method of solving an assignment problem.

6.(a) Differentiate between up-milling and down-milling operations. Show that the mean chip thickness cut during plain milling is given by

$$A_m = \frac{fW}{Nn_t}\sqrt{\frac{d}{D}}$$

where A_m = mean cross-sectional area of the chip f = feed mm/m, N = cutter r.p.m., D = milling cutter diam., d = depth of cut, n_t = no. Of teeth in the cutter, W = width of work piece. 18

(b) During orthogonal cutting of a MS tube at 15 m/min with an HSS tool having 15° rake the chip thickness ratio was 0.35 and the friction force on the tool chip interface measured by means of a special setup was 48 kgf with coefficient of friction 0.6. Estimate the component of the cutting force, shear angle, shear strain and work done in deformation. 24

(c) Compare conventional and high velocity forming methods. Discuss the effect of strain and deformation velocity on forming methods. 18

7.(a) Using Merchant's circle diagram derive the equations to find (i) specific energy of cutting, shear and friction (ii) kinetic coefficient of friction (iii) normal and shear stresses on rake and shear planes. 18

(b) Compare P chart with X and R chart. What are the limitations of X and R charts? 18

(c) Show that when considering the optimum level of inventory Subo which minimises the total expected cost in case of continuous (non-discrete) quantities, the condition to be satisfied is

$$F(s_0) = \frac{C_2}{C_1 + C_2} \text{ where } \quad F(s_0) = \int_0^{s_0} f(r)\,.\,dr$$

$f(r)$ = the probability density function of requirement of r quantity, C_2 = the shortage cost, C_1 = the holding cost per unit of quantity per unit of time. 24

8.(a) What are the essential characteristics of a linear programming ? Explain the terms: key decision, objective, alternatives and restrictions in the context of linear optimization models by assuming a suitable industrial situation. 20

(b) Describe the working principle of a (i) mechanical and (ii) pneumatic comparator. Discuss their relative merits and demerits. Which of the two you would employ for continuous checking of shaft diameter during turning? 20

(c) With reference to quality control discuss the following: (i) Operating characteristic curves (ii) Acceptance sampling (iii) Standard deviation. 20

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) Discuss the feasibility of operating an automobile by means of the energy stored in a tank of compressed air.

(b) Define the Joule-Thomson coefficient and discuss its importance in low-temperature applications.

(c) Real processes involving an interaction of a system and its surroundings will take place only if the net entropy change is greater than zero, or in the limit, remains constant, Prove this.

(d) Write down the boundary layer equations for the flow of an incompressible fluid over a flat plate and explain the significance of each term. How does the boundary layer thickness defined?

2.(a) Does the one-dimensional incompressible flow given by

$$u(y) = Ay^2 + by + C$$
$$v = w = 0$$

where A, B and C are constants, satisfy the continuity equation? 15

(b) Staring with the momentum and continuity equations, derive the velocity profile for the flow between two parallel plates, one of which is at rest and the other moving with a velocity U parallel with the fixed plate. Sketch the velocity distribution for various pressure gradients. 45

3.(a) What are the factors that render processes irreversible? Explain the situations in real life which illustrates the above. 20

(b) Starting from basic differential equation, derive an expression for the temperature distribution in a cylindrical rod in which a uniform heat generation occurs and the surface temperature of the rod is T_S. Mention the assumptions. 40

4.(a) A large tank containing air at 180 kN/m^2 and 300 K discharges into atmosphere through a convergent nozzle. The throat area for the nozzle is 5 cm^2 and atmospheric pressure is 100 kN/m^2. What is the flow rate through this nozzle? If you have to obtain maximum

flow rate through this nozzle, what would you do? Determine the maximum flow rate. Given for air $\gamma = 1.4$ and $R = 287$ J/kg K. 30

(b) Define the effectiveness of a heat exchanger. Derive an expression for the long-mean temperature difference for a counter flow heat exchanger. Mention the assumptions made. 30

Section-B

5. Answer any three of the following parts (answer to each part should be in about 200 words): **20 x 3 = 60**

(a) Distinguish between the carburetion and fuel injections I.C engines.

(b) Give the various classifications of hydraulic turbines with an example for each.

(c) Briefly mention the methods of utilizing the wind energy for power production with examples.

(d) Discuss the phenomenon of surge and choke in centrifugal compressors.

6.(a) In the case of solar collectors which uses an absorption surface, there is a resistance to flow of heat on either side which is fairly high. The cost of the metallic plate used is also high. Discuss a suitable method to collect the solar energy without the costly metallic plates. 30

(b) How does the PWR differ from BWR? Give examples of each. What is a breeder reactor? 30

7.(a) How does a high pressure boiler differ from a low pressure boiler? Give examples of each. 20

(b) A gas turbine operates at a pressure ratio of 6 :1. Inlet air temperature is 15°C. Maximum gas temperature reached is 800°C. Assuming $C_p = 0.24$ for air and gas, calorific value of fuel used is 10000 kcal/kg, polytropic efficiency of compressor and turbine is 0.87. Determine the (i) overall efficiency (ii) specific output (iii) fuel to air ratio (iv) specific fuel consumption. 40

8.(a) Distinguish between the Summer air conditioning and the winter air-conditioning. 10

(b) Why are Freon's expected to be phased out as refrigerants by the end of this century? 10

(c) An air-conditioned space is maintained at 27°C dry bulb and 50 percent relative humidity. The ambient conditions are 40°C dry bulb and 27°C wet bulb. The space has a sensible heat gain of 14 kW. Air is supplied to the space at 7°C saturated. Calculate:

(i) mass of moist air supplied to the space in kg/h;

(ii) latent heat gain of space in kW;

(iii) cooling load of the air washer in kW if 30 per cent of the air supplied to the space is fresh, the remaining being re-circulated. 40