MECHANICAL ENGINEERING Paper I

Time Allowed: Three Hours **Maximum Marks: 200**

INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions.

Candidates should attempt **FIVE** *questions in all. Question No,* **1** *is compulsory.*
Out of the remaining **SIX** *questions attempt any* **FOUR** *questions.*
The number of marks carried by a part of a question are indicated against it.
Answers must be written in **ENGLISH** *only.*
Assume suitable data, if necessary, and indicate the same clearly.
For air R = 0.287 *kJ/kg-K,* C_p = 1.005 *kJ/kg-K,* γ = 1.4, M = 28.97 *kg/kg-mole, Universal gas constant* R = 8.314 *kJ/kg mole-K.*
Unless otherwise mentioned, symbols and notations have their usual standard meanings.
Neat sketches may be drawn, wherever required.
Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly.
Any page or portion of the page left blank in the answer book must be clearly struck off.
A psychrometric chart is attached to this question paper for necessary use by the candidate.

1. (a) Explain the terms (i) coefficient of cubical expansion, β and (ii) coefficient of compressibility K. Hence, show that $\beta/K = (\partial P/\partial T)_V$ 5

(b) Using Maxwell's and other equations, show that

$$C_p - C_v = \left\{P + \left(\frac{\partial u}{\partial v}\right)_T\right\}\left(\frac{\partial v}{\partial T}\right)_P$$

Hence show that

$$C_P - C_V = \beta^2 T v / K.$$ 10

(c) A reversible engine 'A' absorbs energy from a reservoir at temperature T_1 and rejects energy to a reservoir at temperature T_2. A second engine 'B' absorbs the same amount of energy as rejected by engine 'A', from the same reservoir at temperature T_2 and rejects energy to a reservoir at temperature T_3. What will be the relation between T_1, T_2 and T_3 if (i) the efficiencies of both the engines 'A' and 'B' are the same and (ii) the work delivered by both the engines is the same? 15

(d) An ideal gas is heated at constant volume until its temperature is 3 times the original temperature, then it is expanded isothermally till it reaches its original pressure. The gas is then cooled at constant pressure till it is restored to the original state. Determine the net work done per kg of gas if the initial temperature is 350 K. 10

2. (a) Make a detailed comparison of S.I. and C.I engines with respect to basic cycle, fuel, introduction of fuel in the cylinder, ignition, compression ratio, speed, efficiency and weight. 15

(b) Discuss the emissions from S.I. engines and C.I engines. On what factors do these emissions depend? Discuss how these emissions can be controlled. 10

(c) Explain clearly what do you understand by supercharging. How is it achieved? What is the effect of supercharging on the following parameters:
(i) Power Output
(ii) Mechanical Efficiency and
(iii) Fuel Consumption. 15

3. (a) An iron plate of thickness L and thermal conductivity K is subjected to a constant heat flux q_0 W/m^2 at the boundary surface at x = 0. From the other boundary surface at x = L, the heat is dissipated by convection into a fluid at temperature T, with a heat transfer coefficient h. Develop the expressions for the surface temperatures T_1 and T_2 at the surfaces x = 0 and x = L, respectively. For the following data, calculate the surface temperatures T_1 and T_2 if L = 2 cm,

K = 20 W/m°C, q_0 = 105 W/m², T; = 50°C and h = 500 W/m²°C. 15

(b) Explain clearly what do you understand by the, terms velocity boundary layer and thermal boundary layer. Give their importance in the field of engineering. The velocity profile $U_{x,y}$ for boundary layer flow over a flat plate is given by

$$U_{xy} = U_\infty \left\{ \frac{3}{2}\left(\frac{y}{\delta_x}\right) - \frac{1}{2}\left(\frac{y}{\delta_x}\right)^3 \right\}$$

If the boundary layer thickness is given by

$$\delta_x = \sqrt{\frac{280ux}{13U_\infty}}$$

develop the expression for the local drag coefficient C_m over a distance x = L from the leading edge of the plate. 15

(c) Determine the net radiant interchange between two parallel oxidized iron plates, placed at a distance of 30 mm, having size of 4m × 4m. The surface temperatures of the two plates are 120° C and 40° C respectively. The emissivity of both the plates is 0.736. 10

4. (a) An ideal vapour compression refrigerator using Feron-12 operates between temperature limits of - 10° C and 40°C. The refrigerant leaves the condenser dry saturated. The rate of flow of refrigerant through the unit is 150 kg /hr. Calculate the refrigerating effect per kg of refrigerant, the coefficient of performance and the capacity of the plant if,

(i) the refrigerant leaves the condenser dry saturated as stated.

(ii) the refrigerant is sub cooled to 20° C before throttling.

Assume that the enthalpy of refrigerant before throttling is approximately equal to the enthalpy of liquid refrigerant at undercooled temperature of 20° C and take it as h_f = 50.59 kJ/Kg. Give your comments on the result. Solve the problem by using tables. 25

(b) Define human comfort. Give the factors governing optimum effective temperature. Outline the main points considered for cooling load estimate and heating load estimate. 15

5. (a) A ship is sailing in the ocean. The captain of the ship observes an iceberg floating in the sea at a distance and he estimates the visible volume of the iceberg above sea level as 600 m³. If the density of the iceberg is 915 kg/m³, determine the total volume and weight of the iceberg. The density of the sea water may be taken as 1025 kg/m³. 5

(b) Explain practical utility of venturimeter and pitot tube.

Starting from first principles, derive the expression for discharge of a liquid through a venturimeter.

If the coefficient of discharge of a venturimeter is 0.96, the venturimeter constant is 0.3 m 2.5/sec and venturi head is 0.2 m, find discharge through the venturimeter. 15

(c) A city has one million population and water supply to the city is from a reservoir 10 km away. The minimum required water supply is at the rate of 150 liters per head per day. The supply is made in two shifts, each being for 8 hours duration. The full supply level of the reservoir is R.L. 180.00 and its lowest level is R.L. 105.00. The delivery end of the main is at R.L. 22.5 m. The head loss at the delivery of the main is 12 m. Find the diameter of the pipe required. Assume friction factor equal to 0.04. 20

6. (a) A circular cylinder of height 200 mm and radius equal to 80 mm is open at the top. It is fixed on a table at its centre which can be rotated by a motor. Determine the speed of rotation of the table so that one-third of the area of the bottom of the cylinder gets exposed. At the beginning of the rotation the cylinder was filled with a liquid. 10

(b) A cylindrical tank is placed with its axis vertical. A circular orifice of 40 mm diameter is fitted at its bottom. The supply of water into the tank is at uniform rate and at the same time water is discharged through the orifice. A manometer tube is fitted on the side of the tank to indicate the level of the water. An observer starts the stop watch when water level was at 600 mm. It was found that water level becomes 800 mm after one minute Again the observer starts the stop watch when water level was at 1 m and it was found that water level becomes 1.1 m in one minute. Calculate the diameter of the tank by assuming coefficient of discharge for the orifice equal to 0.6. 25

(c) Show that the friction factor is inversely proportional to the Reynolds number in case of laminar flow in circular pipes. 5

7. (a) Explain the terms: stable, unstable and neutral equilibrium in reference to the floating bodies. 6

(b) Compare the velocity profiles for laminar flow and turbulent flow in pipes and comment on them. 4

(c) A reaction turbine has to be designed to develop 370 kW under a head of 70 m while running at speed equal to 750 rpm
Ratio of width of runner to the outer diameter of runner = 0.1
Ratio of inner diameter to the outer diameter = 0.5
Flow ratio = 0.15
Hydraulic efficiency = 95%
Mechanical efficiency = 84%
Circumferential area occupied by thickness of vanes = 5%
Assuming velocity of flow constant, calculate guide vane angle at inlet and runner vane angles at inlet and outlet. The radial velocity is equal to 3.5 m/sec. 30

8. (a) Discuss the importance of dimensional analysis.
Explain clearly Buckingham's π theorem method and Rayleigh's methods of dimensional analysis.
A circular cylinder of a given Length/Diameter ratio is kept in steady rotation at N revol./ sec, in a uniform stream of fluid of velocity v. Assuming that the power required to maintain the motion depends on density ρ, kinematic viscosity ν of the fluid, and the diameter D of the cylinder. Using Rayleigh's method show that

$$P = \frac{\rho \nu^3}{D} f\left(\frac{VD}{\nu}, \frac{ND^2}{\nu}\right)$$ 20

(b) An airplane flies at an altitude with a velocity of 800 km/hr. The pressure and temperature at that altitude are 1.206×10^4 N/m^2 and 217 K respectively. Calculate
(i) the maximum possible temperature on the airplane skin,
(ii) the maximum possible pressure intensity on the airplane body,
(iii) the critical velocity of air relative to the airplane, and
(iv) the maximum possible velocity of the air relative to the airplane. 8

(c) Define Froude number, Reynolds number, Mach number, Euler number and Weber number. 5

(d) Considering Froude number as the criterion of dynamic similarity for a certain flow situation, work out the scale factors for velocity, time, discharge, acceleration, force, work and power in terms of the scale factor for length. 7

MECHANICAL ENGINEERING Paper II

Time Allowed: Three Hours **Maximum Marks: 200**

INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions:

Candidate should attempt **FIVE** *questions in all. Question No.* **1** *in Section* **A** *is compulsory.*

Out of the remaining, attempt **TWO** *from Section-***B** *and* **TWO** *from Section—***C**.

All questions carry equal marks. The number of marks carried by a part of a question is indicated against it.

Answer must be written in **ENGLISH** *only.*

Unless other-wise mentioned, symbols and notations have their usual standard meanings.

Neat sketches may be drawn, wherever required.

All parts and sub-parts of a question are to be attempted together in the answer book.

Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly.

Any page or portion of the page left blank in the answer book must be clearly struck off.

SECTION—A

1. Answer all 20 parts of the question each part carries 2 marks.

(a) State the conditions, which should be satisfied to obtain a kinematically equivalent system with two lumped masses for a connecting rod executing plane motion.

(b) What is meant by hunting in case of engine with governor? Is the degree of hunting more or less in case of isochronous governor as compared to unstable governor?

(c) What is meant by (i) pressure angle, and (ii) pitch point of a cam-follower mechanism?

(d) Define contact ratio of two mating gears and mention its importance in design of gear drive.

(e) How does damping in a single-degree freedom system affect the natural frequency of vibration? Explain its expression in terms of system parameters.

(f) Mention the relationship between three elastic constants i.e., elastic modulus (E), rigidity modulus (C), and bulk modulus (K), for any elastic material. How is the Poisson's ratio (μ) related to these modulii?

(g) State what is meant by kinematic inversion of a mechanism. Name any one of the inversions of double slider-crank mechanism, as used in practice.

(h) If a rod of brittle material is subjected to pure torsion, show with help of a sketch, the plane along which it will fail and state the reason for its failure.

(i) The diameter of a mild steel rod is to be reduced from 70 mm to 65 mm by plain turning in a single pass at speed of 300 rpm and feed of 0.4 mm/rev. Determine the material removal rate (MRR) in cubic centimeter (cc)/min that will occur during the aforesaid machining operation.

(j) Keeping the other parameters same, what will be the effect of increasing the diameter of the straight fluted plain milling cutter on the average uncut chip thickness and why?

(k) How is "Bend Allowance" (BA) calculated in sheet metal working?

(l) How is the wax pattern mode for an investment casting and why is the master pattern made oversize?

(m) What is meant by Basic Length Unit (BLU) of CNC machine tools? Determine the BLU of a CNC machine tool whose work-table is moved by a 4 mm pitch lead screw driven by a stepper motor having 200 steps in one rotation/revolution.

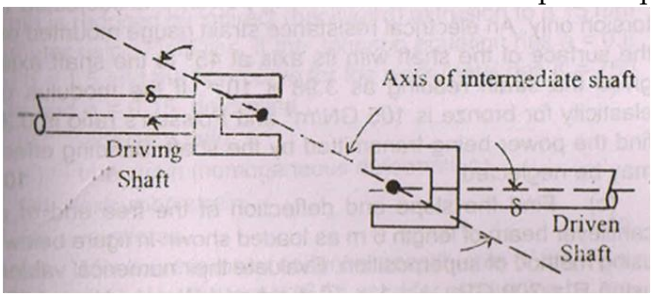
(n) Name any four welding processes which are employed for permanently joining two dissimilar metals.

(o) How fine through holes of diameter less than 50 microns can be made in 1.0 mm thick aluminum sheets?

(p) Mention the relative advantageous characteristics of polymer products and their manufacturing over those of similar metal products.
(q) Enumerate four purposes of keeping inventory.
(r) What are the properties to be satisfied by a competitive situation to be called a "GAME" with reference to operation research?
(s) Define "Dynamic Programming" and Bellman's principle of optimality.
(t) Illustrate the simplest form of ALLOCATION PROBLEM by Three Mathematical Equations.

SECTION—B

2. (a) Two parallel shafts indicated in figure below are connected by an intermediate shaft with a Hooke's joint at each end. Show how the joints should be oriented to obtain a constant angular velocity ratio between the driving and driven shafts. The intermediate shaft of the above arrangement has a moss moment of inertia 3 gm^2 and is inclined at 30° to the axes of the driving and driven shafts. If the driving shaft rotates uniformly at 2400 rpm with a steady input torque of 300 Nm, determine the maximum fluctuation of the output torque. 20



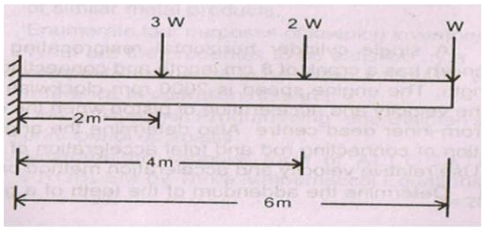
(b) A single cylinder horizontal reciprocating engine mechanism has a crank of 8 cm length and connecting rod 36 cm length. The engine speed is 2000 rpm clockwise. Determine the velocity and acceleration of piston when the crank is 315° from inner dead centre. Also determine the angular acceleration of connecting rod and total acceleration of its mid-point. Use relative velocity and acceleration method only. 10

(c) Determine the addendum of the teeth of a gear pair consisting of two spur wheels each having 30 teeth to have a minimum contact ratio equal to 2. The circular pitch is 2.5 cm and pressure angle is 20°. 10

3. (a) A steel bolt of diameter 10 mm passes through a brass tube of internal diameter 15 mm and external diameter 25 mm. The bolt is tightened by a nut so that the length of tube is reduced by 1.5 mm. If the temperature of the assembly is raised by 40°C, estimate the axial stresses in the bolt and the tube before and after heating. Material properties for steel and brass are: $E_S = 2 \times 10^5$ N/mm^2, $\alpha_S = 1.2 \times 10^{-5}$/°C and $E_b = 1 \times 10^5$ N/mm^2, $\alpha_b = 1.9 \times 10^{-5}$/°C. 10

(b) A solid phosphor bronze shaft 60 mm in diameter is rotating at 800 rpm and transmitting power. It is subjected to torsion only. An electrical resistance strain gauge mounted on the surface of the shaft with its axis at 45° to the shaft axis, gives the strain reading as 3.98×10^{-4}. If the modulus of elasticity for bronze is 10^5 GN/m^2 and Poisson's ratio is 0.3, find the power being transmitted by the shaft. Bending effect may be neglected. 10

(c) Find the slope and deflection at the free end of a cantilever beam of length 6 m as loaded shown in figure below, using method of superposition. Evaluate their numerical values using E = 200 GPa, $I = 1 \times 10^{-4}$ m^4 and W = 1 kN. 10



4. (a) A steel rod of diameter 50 mm is forced into a bronze casing of outside diameter 90 mm, producing a tensile hoop stress of 30 MPa at the outside diameter of the casing.
(i) the radial pressure between the rod and the casing,
(ii) the shrinkage allowance and
(iii) the rise in temperature which would just eliminate the force fit.
Assume the following material properties: $E_S = 2 \times 10^5$ N/mm^2, $\mu_S = 0.25$; $\alpha_S = 1.2 \times 10^{-5}$/°C and $E_b = 1 \times 10^5$ N/mm^2, $\mu_b = 0.3$, $\alpha_b = 1.9 \times 10^{-5}$/°C. 20

(b) A cylindrical billet of 40 mm diameter and 100 mm length is reduced by indirect (backward) extrusion to a 15 mm diameter using Flat Dies. If the Johnson equation has a = 0.8 and b = 1.5 and the flow curve for the work metal has K = 750 MPa and n = 0.15, determine:
(i) extrusion ratio
(ii) true strain (homogeneous deformation)
(iii) extrusion strain
(iv) ram force. 10

(c) Mention the major essential constituents of any Flexible Manufacturing System (MFS) used for production by machining. Also state the basic functions of those constituents (sub systems). 10

SECTION—C

5. (a) Compare the solidification time of two optimum side-risers of the same volume when one has a cylindrical shape and the other is of square parallelepiped. 20

(b) Name the processes by which external screw thread can be produced (both manually using tools and in machines). 10

(c) For resistance spot welding of two aluminum sheets each 2 mm thick, a current of 5000 A was passed for 0.15 sec. The total resistance was estimated to be 75 μΩ and the nuggest diameter and thickness were measured to be 5 mm and 2.5 mm respectively. What would be the proportion of heat energy utilized for welding if the melting energy per unit volume for aluminum is taken as 2.9 j/mm^3? 10

6. (a) During turning a carbon steel rod of ,160 mm diameter by a carbide tool of geometry; 0°, 0°, 10°, 8°, 15°, 75°, 0 (mm) at speed of 400 rpm, feed of 0.32 mm/rev. and 4.0 mm depth of cut, the following observations were made:
Tangential component of the cutting force, P = 1200 N.
Axial component of the cutting force, P_x = 800 N
Chip thickness (after cut), α_2 = 0.8 mm.
For the above machining condition determine the values of
(i) Friction force, F and normal force, N acting at the chip-tool interface.
(ii) Yield shear strength of the work material under this machining condition.
(iii) Cutting power consumption in kW. 20

(b) When a rectangular section, 100 mm wide and 60 mm thick, is rolled to some thickness in one pass with rolls of 400 mm diameter in hot rolling, where coefficient of friction is 0.3,
(i) What is the highest possible reduction in that pass?
(ii) What will be the "length of contact" with the rolls?
(iii) If the mean rolling pressure is 500 MPa, what is the total rolling load? 10

(c) (i) What are the detrimental effects of the high cutting temperature on the

machined product and the cutting tool?

(ii) How can such cutting temperature be reduced without sacrificing productivity? 6 + 4 = 10

7. (a) A certain company produces tea trays and ash trays out of sheet metal. Following data is given on capacity availability and economics of each product:

Department	Time taken for		Available time
Ash tray		Tea tray	
Stamping	10 sec	20 sec	30,000 sec
Forming	15 sec	5 sec	30,000 sec.

Determine the optimum production schedule. Each ash tray contributes Rs. 20 to the gross profit and each tea tray contributes Rs. 30 to the gross profit. Total daily fixed costs amount to Rs. 45,000. Solve this problem graphically. What is the maximum net profit per day at the optimum production level, including the effect of fixed cost? 20

(b) What is a "Trend Line" in sales forecasting by Time Series Analysis? In a company the sales figures for a particular product for 16 consecutive quarters were recorded as follows:

Quarter	Units sold
1	1000
2	3000
3	4000
4	2000
5	1000
6	3000
7	5000
8	3000
9	2000
10	4000
11	6000
12	3000
13	2000
14	5000
15	7000
16	4000

Determine the trend line for this product. 10

(c) With reference to critical path method define the following terms with a brief description of each of them:

(i) Critical path

(ii) Project graph

(iii) Early start and early finish times. 10