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) A finite thermal system having heat capacity, C = 0.04 T^2, J/K is initially at 600 K. Estimate the maximum work obtainable from the thermal system if the surroundings is at 300 K. 8

(b) State Gouy-Stodola theorem of irreversibility. Estimate the irreversibility associated with the expansion process of air through a very small constriction in a pipe from pressure and temperature, respectively of 8 bar and 600 K to pressure of 1.2 bar. Assume air to be an ideal gas. The temperature of surroundings is 25° C. 7

(c) A tank contains 50 kg of water initially at a temperature of 30° C. Water at the rate of 200 kg/h and temperature of 30° C enters the tank through an Inlet pipe. A cooling coil immersed in the tank removes heat energy from water at the rate of 8 kW. A mechanical stirrer ensures thorough mixing of water in the tank so as to maintain a uniform temperature of water at any instant and in the process add heat energy at the rate of 0.2 kW to water.
Neglecting kinetic and potential energy changes and taking the average specific heat of water as 4.2 kJ/ kg-K, derive an expression for the variation of instantaneous temperature of water in the tank with respect to time. 10

(d) Show that the properties at the critical state for a gas obeying van der Waals equation of state

$$P = \frac{RT}{V-b} - \frac{a}{V^2}$$

are given by

$$P_c = \frac{a}{27b^2},\ V_c = 3b, \text{ and } T_c = \frac{a}{27Rb}$$

Hence show that the coefficients 'a' and 'b' are expressed as

$$a = \frac{27R^2T_c^2}{64P_c}, \text{ and } b = \frac{RT_c}{8P_c}$$

the critical coefficient for the van der Waals gas is 2.66. 15

2. (a) What is supercharging of diesel engine power plant? What are its objectives? Discuss various methods of supercharging. 15

(b) The following data are known for a four cylinder four stroke petrol engine:
Cylinder dimensions: 11 cm bore, 13 cm stroke; engine speed: 2250 rpm; brake power: 50 kW; friction power: 15 kW; fuel consumption rate: 10.5 kg/h; calorific value of fuel: 50,000 kJ/kg; air inhalation rate: 300 kg/h; ambient condition: 15° C, 103 bar. Estimate (i) brake mean effective pressure (ii) volumetric efficiency (iii) brake thermal efficiency, and (iv) mechanical efficiency. 10

(c) Using a simple vertical sectional diagram, explain the function of principal components of the nuclear reactor of a pressurized water reactor (PWR) nuclear power plant. List the advantages and disadvantages of PWR nuclear power plant. 15

3. (a) A copper sphere weighing 3 kg is heated in a furnace to a temperature of 300°C and is suddenly taken out and allowed to cool in ambient air at 25°C. If it takes 60 min for the copper sphere to cool down to 35°C, what is the average surface heal transfer coefficient? Take density of copper sphere 8950 kg/m^3 and specific heat C_p = 0.383 kJ / Kg°C.
State the assumptions made and derive the relation used. 10

(b) From the Von Karman's Integral momentum equation for the laminar boundary layer under forced convective conditions, obtain the expressions for the hydrodynamic boundary layer thickness and the drag coefficient for the case of a linear velocity profile in the boundary layer. 10

(c) The base of a rectangular enclosure (150 cm × 100 cm) and height 150 cm is maintained at 500° C. The top surface is held at 350° C. If the side walls are perfectly insulated and the surfaces are diffuse grey with an emissivity of 0.7, calculate (i) the net rate of heat supply to the base, (ii) If the skin temperature of the outside of the top wall is at 70° C and heat loss from this surface to a big factory shed at 30° C, what is the convective heat transfer coefficient at this surface? 20

4. (a) The discharge Q over a V-shaped notch is known to depend on the angle θ of the notch, the heat H of the water surface, the velocity of approach V_0 and the gravity g. Find the dimensionless form of the discharge equation. 10

(b) If gravity, viscosity and surface tension are equally important in a model, show that for dynamic similarity, the relationship between viscosity ration μ_r, surface tension ratio σ_r and model scale ratio L_r is given by

$$\frac{\mu_r L_r^{1/2}}{\sigma_r} = 1$$ 15

(c) A thin rectangular plate 10 m long and 2 m wide is to be towed in sea water at a steady speed of 5 m/s. Both the surfaces of the plate are rough, whose roughness magnitude is assumed as 5 mm. Estimate the power required to tow the plate. Assume ρ = 1020 kg/m^3 and μ = 00018 Pa.s. 15

5. (a) By using the energy equation

$$V.dv + \frac{d\rho}{\rho} + d(losses) = 0$$

the continuity equation ρAV = constant, and

$$C = \sqrt{\frac{dP}{d\rho}}$$

show that for subsonic flow in a pipe, the velocity must increase in the downstream direction. 10

(b) Show that oblique and normal shock waves in a gas are analogous to open-channel waves when the open channel width is constant. 15

(c) Helium enters a 100 mm-1D pipe from a converging-diverging nozzle at M = 1.30, P = 14 kPa, T = 225 K. Estimate for an isothermal flow (i) the maximum length of pipe for no choking, (ii) the downstream conditions, and (iii) the length from the exit to the section where M = 1.0, f = 0.016. 15

6. (a) A horizontal pipe of diameter D_1, has a sudden expansion to a diameter D_2. At what ratio D_1/D_2 would the differential pressure on either side of the expansion be maximum? What is the corresponding loss of head and differential pressure head? 10

(b) In an isentropic flow, for flow conditions termed critical at the throat section, show that for an air flow having K = 1.4, the absolute temperature drops about 17% from reservoir to throat, the critical pressure is 52.8% of the reservoir pressure and the density is reduced by 37%. 15

(c) The frictional torque T of a disc of diameter D rotating at a speed N in a fluid of viscosity ν and density ρ in a turbulent flow is given by

$$T = D^5 N^2 \rho \phi \left[\frac{\mu}{D^2 N \rho} \right]$$

Prove this by the method of dimensions. 15

7. (a) A jet of water makes an angle with the direction of motion of a series of moving blades. If the blade angle at inlet and outlet are θ and ϕ with the direction of motion, derive an expression for the work done. If there is no shock at entry, show that the maximum efficiency that can be achieved from the system is

$$\eta_{\max} = \frac{\cos^2 \alpha}{2} \left[1 + \frac{K.\cos\phi}{\cos\theta} \right] \text{ assume } K = \frac{V_{r2}}{V_{r1}}$$

Also state what would be the maximum efficiency for semi-circular vanes when K = 1. 15

(b) Discuss briefly the classification of a hydroelectric plant based on
(i) availability of water head
(ii) nature of load capacity. 10

(c) During a trial run on a pump, cavitation occurred when the sum of static pressure and velocity head at inlet was reduced to 3.2 m. The pump total head was 35 m at a discharge of 0.045 m^3/sec. The vapour pressure of water = 1.8 kPa and the barometer pressure = 750 mm of Hg. If the pump is to operate at some other location where the atmospheric pressure was reduced to 620 mm of Hg and the temperature is so reduced that the vapour pressure of water is 830 Pa, what is the value of cavitation parameter when the pump develops the same total head and discharge? Is it necessary to reduce the height of the pump and if so, by how much? 15

8. (a) A two stage compression with intercooling in between stages and a single stage turbine with regeneration is employed in an open cycle gas turbine plant. Air at 1 bar and 15° C enters the compressor and the maximum pressure ratio is 5 and the maximum temperature in the cycle is 800° C. The rate of air flow through the cycle is 250 kg/ sec and the calorific value of the fuel used is 42 MJ/kg. The isentropic efficiencies of both the compressors is 0.8 and the effectiveness of the regenerator is 0.7, and the isentropic efficiency of the turbine is 0.9. The combustion efficiency is 0.95, the mechanical efficiency is 0.96 and the generator efficiency is 0.75. Take C_p of air = 1.005 kj/kg K and γ = 1.4 and for gases C_p = 1.08 KJ/kg K and γ = 1.33. Assuming perfect intercooling and neglecting pressure and heat losses, determine
(i) the air fuel ratio
(ii) the cycle efficiency
(iii) the power supplied by the plant
(iv) the specific fuel consumption and the fuel consumption per hour. 15

(b) What is a supercritical boiler? What are its merits and demerits? 8

(c) In a reaction turbine with radial vanes at inlet, the velocity of flow at outlet is 'K' times that at inlet. Prove that

$$\eta_h = \frac{2}{2 + K^2 \tan^2 \alpha}, \; u_1 = \sqrt{\frac{2gH}{2 + K^2 \tan^2 \alpha}}$$ 10

(d) Why are steam turbines compounded? What are the different methods of compounding? 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) Under what conditions of relative motion between links of a mechanism, Coriolis component of acceleration is generated? Express its magnitude, direction and sense with the help of a sketch.

(b) What is the law of gearing? Express the magnitude of sliding velocity at the point of contact between two meshing gears and its value at pitch point.

(c) An accelerometer indicates that a structure is vibrating at 80 c.p.s. with a maximum acceleration of 50g. Determine amplitude of vibration of the structure.

(d) In a two-cylinder V-engine having 90° including angle between the cylinder axes has crank length equal to 10 cm and reciprocating mass for each cylinder equal to 10 kg. If the crank rotates at 500 r.p.m., determine primary unbalanced force in the engine.

(e) What different stresses set up in a bolt due to initial tightening, while used as a fastener? Name all the stresses in detail.

(f) Name the four principal types of roller bearings.

(g) A prismatic bar in compression has a cross-sectional area A = 900 mm^2 and carries an axial load P = 90 kN. What are the stresses acting on -
  (i) a plane transverse to the loading axis;
  (ii) a plane at $\theta = 60°$ to the loading axis?

(h) A thin cylindrical pressure vessel of inside radius r and thickness of metal t is subjected to an internal fluid pressure p. What are the values of -
  (i) maximum normal stress;
  (ii) maximum shear stress?

(i) A hollow shaft and a solid shaft constructed of the same material have the same length and the same outside radius. The inside radius of the hollow shaft is 0.6 times of the outside radius. Both the shafts are subjected to the same torque.
  (i) What is the ratio of maximum shear stress in the hollow shaft to that of solid shaft?
  (ii) What is the ratio of angle of twist in the hollow shaft to that of solid shaft?

(j) (i) Define 'ductility' of metals.
  (ii) Arrange the metals mild steel, aluminium, zinc and copper in order of their diminishing ductility (highest first-lowest last).

(k) What is extrusion? Name the process for manufacturing collapsible tubes and draw figures to show the process.

(l) Name the casting methods by which the following products are made :
  (i) Gear blanks

(ii) Blades for gas turbines
(iii) Carburettors
(iv) Hollow pipes

(m) Draw labeled figures to show the following, in case of oxy-acetylene welding:
(i) Carburizing flame
(ii) Oxidizing flame

(n) What is the function of manipulator in a robot? Classify robots as per their path control.

(o) What is meant by hot hardness, in case of tool materials? Name any two tool materials which are not suitable for low speed applications.

(p) Name three types of fits and show a labelled diagram of a clearance fit.

(q) What is meant by break-even point? Draw a figure to illustrate your answer.

(r) Is Material Requirement Planning a material planning system, a production planning system, or both? Explain.

(s) What are the differences between transportation and assignment problems, in relation to -
(i) structure of the problem;
(ii) procedure for solving?

(t) What are pointers? Explain their use with a suitable program.

SECTION—B

2. (a) A copper rod 6 cm in diameter is placed within a steel tube, 8 cm external diameter and 6 cm internal diameter, of exactly the same length. The two pieces are rigidly fixed together by two transverse pins 20 mm in diameter, one at each end passing through both rod and the tube. Calculate the stresses induced in the copper rod, steel rube and the pins if the temperature of the combination is raised by 50 °C. Take:
E_s = 210 GPa, α_s = 0.0000115/°C
E_c = 105 GPa, α_c = 0.000017/°C 15

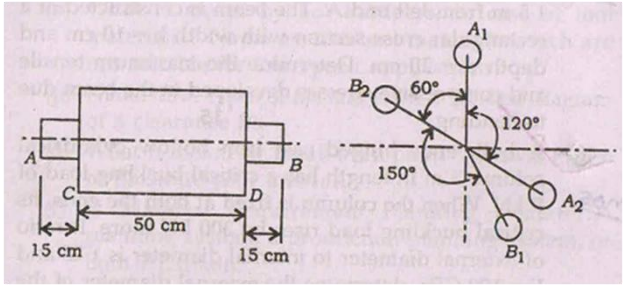
(b) A simply supported beam AB of span length 4 m supports a uniformly distributed load of intensity q = 4 kN/m spread over the entire span and a concentrated load P = 2 kN placed at a distance of 1.5 m from left end A. The beam is constructed of a rectangular cross-section with width b = 10 cm and depth d = 20 cm. Determine the maximum tensile and compressive stresses developed in the beam due to bending. 15

(c) A both ends hinged cast iron hollow cylindrical column 3 m in length has a critical buckling load of P kN. When the column is fixed at both the ends, its critical buckling load rises by 300 kN more. It ratio of external diameter to internal diameter is 1.25 and E = 100 GPa, determine the external diameter of the column. 10

3. (a) (i) A close-coiled helical spring has coil diameter D, wire diameter d and number of turns n. The spring material has a shearing modulus G. Derive an expression for the stiffness K of the spring. 5

(ii) A Close-coiled helical spring has coil diameter to wire diameter ratio of 6. The spring deflects 3 cm under an axial load of 500 N and the maximum shear stress is not to exceed 300 MPa. Find the diameter and the length of the spring wire required. Shearing modulus of wire material = 80 G. 15

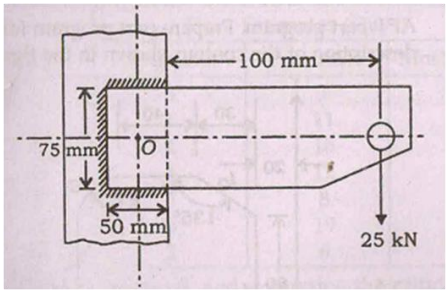
(b) A rotor is balanced by attaching two 2 kg trial masses in each of the planes A and B as shown in the figure below at a radius of 15 cm. Complete dynamic balance is obtained with the angular positions shown in the same figure. Determine the position and mass of the material to be removed from each of the planes C and D at a radius of 10 cm in order to balance the rotor when the trial masses are removed.



20

4. (a) A vertical steel shaft of 15 mm diameter is held in long bearing 1 m apart and carries at its middle a disc of mass 15 kg. The eccentricity of the centre of gravity of the disc from the centre of the shaft is 0.30 mm. The modulus of elasticity for the shaft material is 200 GPa and the permissible stress is 70 MPa. Determine the critical speed of the shaft neglecting the mass of the shaft and the range of speed over which it is unsafe to run the shaft. 20

(b) Determine the size of the weld required for static loading in the eccentrically loaded weld as show in the figure below. Allowable stress for the weld may be taken as 75 N/mm^2. O is the CG of the weld area.



20

SECTION—C

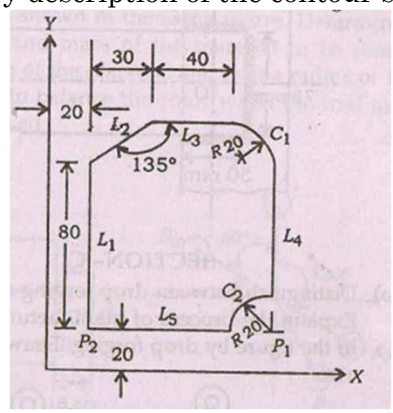
5. (a) Distinguish between drop forging and press forging. Explain the process of manufacturing a part shown in the figure by drop forging. Draw suitable sketches also.

15

(b) Calculate the size of a cylindrical riser, whose height and diameter are equal, to feed a steel slab casting 10 cm × 30 cm × 6 cm with a side riser. Casting is poured horizontally into the mould. Use modulus method. 10

(c) What is an arc blow? How is the arc blow problem taken care of in welding? Calculate the melting efficiency in case of arc welding of steel with a potential of 20 V and current of 200 A. The travel speed is 5 mm/sec and the cross-sectional area of the joint is 20 mm^2. Heat required to melt steel may be taken as 10 J/mm^3 and the heat transfer efficiency as 0.85. 15

6. (a) Name the four types of statements in a complete APT part program. Prepare part program for geometry description of the contour shown in the figure below:



(b) What are the desirable properties that diamond cutting tool materials have? State the functions of electrolyte and the properties it should have in case of electrochemical machining. 10

(c) Define the terms tolerances, limits and fits with reference to dimensional measurement. What is a comparator? How does it differ from a measuring instrument? What do you understand by the terms hole basis and shaft basis in terms of assembly fit specifications? Which is preferred and why is it preferred? 15

7. (a) A project consists of 7 jobs. Jobs A and F can be started and completed independently. Jobs B and C can start only after job A has been completed. Jobs D, E and G can start only after jobs B, (C and D) and (E and F) are completed, respectively.

Time estimates of all the jobs are given in the following table:

Job	Time Estimates (Days)		
	Optimistic	Pessimistic	Most Likely
A	3	7	5
B	7	11	9
C	4	18	14
D	4	12	8
E	4	8	6
F	5	19	12
G	2	6	4

Draw the network and determine the critical path, and its expected duration (T_e). What is the probability of completing the project in T_e days? Also, determine the total & free slacks of all the jobs. 15

(b) Name the three costs involved in inventory control.

A store procures and sells certain items. Information about an item is as follows:

Expected annual sales = 8000 units

Ordering cost = Rs 1,800 per order

Holding cost = 10% of average inventory value

The items can be purchased according to the following schedule:

Lot Size	Unit Price (Rs)
1 - 999	220
1000 - 1499	200
1500 - 1999	190
2000 and above	185

Determine the best order size. 10

(c) Draw a flow chart and write a program in C to find out the diameter of a solid steel shaft to transmit 20 kW power at 200 r.p.m. The ultimate shear stress for steel is 360 MPa and the factor of safety is 8. 15