MECHANICAL ENGINEERING Paper I

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

QUESTION PAPER SPECIFIC INSTRUCTIONS

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

There are **EIGHT** questions in all, out of which **FIVE** are to be attempted.

Question No. **1** and *5* are compulsory. Out of the remaining **SIX** questions, **THREE** are to be attempted selecting at least **ONE** question from each of the two **Sections A** and **B**.

Attempts of questions shall be counted in sequential 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 Question-cum-Answer Booklet must be clearly struck off.

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

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

Unless otherwise mentioned, symbols and notations have their usual standard meanings. Assume suitable data, if necessary and indicate the same clearly. Neat sketches may be drawn, wherever required.

SECTION 'A'

1. Answer any four of the following (each answer should conform to a limit of around 150 words):

(a) An eccentrically hinged circular disc is used to drive an offset, flat faced follower in the vertical direction.
Sketch this mechanism indicating the direction of cam rotation. Also draw the equivalent mechanism consisting of only lower pairs. State the fundamental law of gearing and prove this by using Aronhold-Kennedy theorem of three centres. 2 + 2 + 2 + 4

(b) Explain with examples the difference between an open loop and a closed loop control system. For a first order linear control system, explain geometrically the concept of time constant. Also explain its physical significance. 5 + 3 + 2

(c) Explain the difference between metals and alloys. What are solid solutions? Write down the difference between interstitial solid solutions and substitutional solid solutions. With neat sketches, show the difference between BCC and FCC crystals. 2 + 2 + 3 + 3

(d) A hollow shaft having an inside diameter 60% of its outside diameter is to replace a solid shaft transmitting same power at same operating speed. Determine the percentage saving in material, if the material to be used for both the cases is also the same. 10

(e) With the help of sketches, show the stress-strain relationship for both ductile and brittle materials. Indicate the following points on the relevant sketches:
(i) Yield point (ii) Ultimate stress (iii) Breaking stress (iv) Elastic limit (v) Proportional limit (vi) Proof stress 2 + 2 + 6

2. (a) The length of a connecting rod of an engine is 500 mm measured between the centres and its mass is 18 kg. The C.G. is 125 mm from the crank pin centre and the crank radius is 100 mm. Determine the dynamically equivalent system keeping one mass at the small end. The frequency of oscillations of the rod when suspended from the centre of small end is 43 vibrations per minute. 15

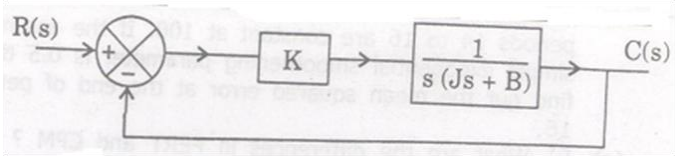
(b) An open belt drive connects two flat pulleys, the smaller pulley being of 400 mm in diameter. The angle of lap on the smaller pulley is 160° and the coefficient of friction between belt and pulley is 0.3. Which of the following alternatives will be more effective in increasing the power transmission capacity:
(i) increasing the initial tension by 10%.
(ii) increasing the coefficient of friction by 10% by the application of suitable dressing to the belt. 8 + 7

(c) Derive the expression for the minimum number of teeth on a pinion for involute rack in order to avoid interference. 10

3. (a) A reciprocating pump of mass 200 kg is driven through a belt by an electric motor at 3000 rpm. The pump is mounted on isolators with total stiffness of 5 MN/m and damping coefficient of 3.125 kN s/m. Determine the vibratory amplitude of the pump due to fundamental harmonic force of excitation 1 kN. Also determine the maximum vibratory amplitude when the pump is switched on and the motor speed passes through resonant condition. 10 + 10

(b) A machine punching 3.8 cm diameter holes in a 3.2 cm thick plate does 600 Joules 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 velocity of the flywheel at its radius of gyration is 27.5 m/s. Find the weight of the flywheel so that its velocity at the same radius does not fall below 24.5 m/s. Also determine the kW rating of the motor. 8 + 2

(c) For the closed loop control system shown in the figure below, show that the steady state error in following the unit ramp input is B/K. This error can be made smaller by choosing B small and/or K large would have the effect of making the damping ratio small, which is normally not desirable. Describe a method or methods to make B/K small and yet make damping ratio have reasonable value ($0.5 < \xi < 0.7$). 5 + 5



4. (a) A compound cylinder is made by shrinking a cylinder of outer diameter 180 mm over another cylinder of inner diameter 90 mm. If the numerical value of the maximum hoop stress developed due to shrinkage fitting in both cylinders be same, find the junction diameter. 10

(b) An ISJB 150 rolled steel joist is simply supported over a span of 4 m. A weight of 380 N is dropped onto the middle of the beam, producing an instantaneous stress of 80 N/mm^2. Calculate the height from which the weight was dropped and the maximum deflection in the beam.
Assume I = 322.1 cm^4 and E = 200 GPa, Depth of the beam = 150 mm. 7 + 8

(c) Determine the rise in temperature in order to induce buckling in a 1.0 meter long circular rod of diameter 40 mm. Assume the rod to be pinned at its ends and the coefficient of thermal expansion is 20×10^{-6}/°C. Assume also uniform heating of the rod. 8

(d) A beam 5 m long, hinged at both ends is subjected to an anticlockwise moment M equal to 60 kNm at a point 3 m away from one end. Draw the S.F. and B.M. diagrams. 3 + 4

SECTION 'B'

5. Answer any four of the following (each answer should conform to a limit around 150 words):

(a) (i) How is an electrolyte selected for electrochemical machining process?
(ii) Enumerate the classification of fits based on negative, positive and zero value of clearance. Give one example of each. 5 + 5

(b) In a forecasting model, at the end of period 13, the forecasted value for period 14 is 75. Actual value in the periods 14 to 16 are constant at 100. If the assumed simple exponential smoothening parameter is 0.5 then find out the mean squared error at the end of period 16. 10

(c) (i) What are the differences in PERT and CPM?
(ii) A PERT activity has an optimistic time of three days, pessimistic time of 15 days and the expected time is 7 days. Find out the most likely time of the activity. 5 + 5

(d) (i) 10 mm diameter holes are to be punched in a steel sheet of 3 mm thickness. Shear strength of material is 400 N/mm2 and penetration is 40%. Shear

provided on the punch is 2 mm. What will be the blanking force during operation?

(ii) Derive an expression for shear stress in the chip in orthogonal cutting operation for a single point cutting tool. 5 + 5

(e) Calculate the material removal rate and electrode feed rate in the electrochemical machining of an iron surface that is 25 mm × 25 mm in cross-section, using NaCI in water as electrolyte. The gap between the tool and the work-piece is 0.25 mm. The supply voltage is 12 volt D.C. The specific resistance of electrolyte is 3 Ω cm. Take for iron: Valency = 2; Atomic weight = 55.85; Density = 7860 kg/m^3. 5 + 5

6. (a) (i) In a general hospital, the demand for disposable plastic tubing in general surgery department for the last two months is November — 200 units, December — 250 units. Using 150 units as the November forecast and a smoothing coefficient of 0.7, calculate the forecast for January.

(ii) What are the stages for value analysis? 5 + 5

(b) Calculate the drawing load required to obtain 30% reduction in area on a 10 mm diameter copper wire. The following data is given:

$$T_0 = 240 \text{ N/mm}^2,\ 2\alpha = 12°,\ \mu = 0.10$$

Also calculate the power of electric motor if the drawing speed is 2.5 m/sec. Take efficiency of the motor as 95%. 5 + 5

(c) What are the functions of inventory control? In ABC analysis how are 'A' items controlled? 5 + 5

(d) What is the use of a sine bar? State the necessary conditions to be satisfied for accurate measurement. 5 + 5

7. (a) Describe the process of plasma arc machining with a neat schematic diagram. 10

(b) Determine the percentage change in the machining time for an ultrasonic machining operation cutting tungsten carbide plates when the tool material is changed from copper to stainless steel. Assume hardness of stainless steel to be 3 times higher than that of copper. 10

(c) Describe the principle of operation of an NC machine tool with a flow diagram. 10

(d) Describe what do you mean by linear interpolation and circular interpolation in NC machine tools progiamming. Draw the sketches. 5 + 5

8. (a) A self service store employs one cashier at its counter. Customers arrive at an average every 5 minutes, while the cashier can serve 10 customers at the same time. Assuming Poisson distribution for service rate determine:

(i) Average number of customers in the system.

(ii) Average number of customers in the queue.

(iii) Average time a customer spends in the system.

(iv) Average time a customer spends in the queue. 5 + 5 + 5 + 5

(b) A company is manufacturing two different products A and B. Each product is to be processed in three departments - casting, machining and finally inspection. The capacity of 3 departments is limited to 35 hours, 32 hours and 24 hours per week respectively. Product A requires 7 hours in casting department, 8 hours in machining shop and 4 hours in inspection whereas product B requires 5 hours, 4 hours and 6 hours respectively in respective shops. The profit contribution for a unit product of A and B is Rs. 30/- and Rs. 40/ - respectively.

(i) Formulate the problem.

(ii) Find out the optimal qualities of products A and B. 10 + 10

MECHANICAL ENGINEERING Paper II

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

QUESTION PAPER SPECIFIC INSTRUCTIONS

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

*There are **EIGHT** questions in all, out of which **FIVE** are to be attempted.*

*Question No. **1** and **5** are compulsory. Out of the remaining **SIX** questions, **THREE** are to be attempted selecting at least **ONE** question from each of the two **Sections A** and **B**.*

Attempts of questions shall be counted in sequential 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 Question-cum-Answer Booklet must be clearly struck off.

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

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

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary and indicate the same clearly.

Neat sketches may be drawn, wherever required.

Newton may be converted to kgf using the equality 1 kilonewton (1 kN) = 100 kgf, if found necessary.

All answers should be in SI units.

Take: 1 kcal = 4.187 kJ and 1 kg/cm^2 = 0.98 bar

1 bar = 10^5 pascals

Universal gas constant = 8314.6 J/kmol-K

Psychrometric chart is enclosed.

SECTION—A

1. Answer any four parts:

(a) (i) An inventor claims to have developed an engine which draws 1000 kJ of heat energy per cycle each from two thermal reservoirs at temperatures 1500 K and 900 K and rejects 1600 kJ of heat energy per cycle to a thermal reservoir at 300 K while performing 400 kJ per cycle of work. Examine the validity of the claim using first law of thermodynamics and inequality of Clausius. 5

(ii) Using appropriate T-ds relations, show that the slope of the constant volume line is higher than that of a constant pressure line passing through a given state represented on a temperature-entropy diagram for a perfect gas. Sketch the temperature-entropy diagram. 5

(b) Equal amounts of water, initially at different temperatures of T_1 and T_2 ($T_1 > T_2$) are mixed adiabatically and isothermally till the mixture reaches a final equilibrium temperature of T_f. Show that the mixing is an irreversible process. Assume constant & same specific heat for both the amounts of water. 10

(c) (i) Two black discs of diameter 0.6 m are placed parallel and facing each other with a centre to centre distance of 0.5 m and are at constant temperatures of 1000 K and 300 K respectively. Calculate the net radiation heat exchange between the discs, if no other surface receives radiation and convection heat transfer is negligible. Take shape factor $F_{1\text{-}2} = 0.8$ and $\sigma = 5.67 \times 10^{-8}$ W/m^2-K^4. 5

(ii) Water enters a very long tube having an inner diameter of 0-01 m with velocity and temperature, respectively, at 0.01 m/s and 30 °C. If a constant and uniform heat flux is imposed on the tube, estimate its value when the average difference between the inner tube surface temperature and bulk mean temperature of water is 10 °C.

Take ρ = 990 kg/m^3; $\nu = 0.65 \times 10^{-6}$ m^2/s; C = 4178 J/kg-K; k = 0.62 W/m-K, Pr = 4.3. 5

(d) With the help of suitable diagrams, distinguish between surface resistance and space resistance used in radiation network analysis for ideal gray diffuse surfaces constituting an enclosure. 10

(e) (i) Compare the main factors that can reduce knocking is SI and CI engines. 5

(ii) List the various constituents of exhaust of an IC engine. How are they measured? 5

2. (a) The following data pertain to the testing of a four-cylinder, four-stroke diesel engine:
Bore = 40 cm, Stroke = 44 cm, Speed = 400 r.p.m., bp = 380 kW, mep = 7.5 bar, Fuel consumption = 85 kg/hr, Lower calorific value of fuel = 44 MJ / kg, Air consumption = 35 kg/min, Mass of jacket water = 98 kg/min, Rise in temperature of jacket cooling water = 40°C, Amount of piston cooling oil = 54 kg/min, Temperature rise of cooling oil = 24 °C, Specific heat of cooling oil = 2.09 kJ/kg-K, Room temperature = 20 °C, Exhaust gas temperature = 320 °C, C_p of dry exhaust gas = 1.045 kJ/kg-K.
Draw up the heat balance and calculate mechanical efficiency and brake specific consumption at half-load if friction power remains the same. Comment on the results in the light of modern diesel engines. 20

(b) With the help of a neat sketch, discuss the working principle of individual pump injection system for compression ignition engine. 10

(c) Discuss the parameters affecting internal combustion engine heat transfer. 10

3. (a) Using an appropriate form of heat conduction equation for steady radial conduction in a solid cylinder of radius R, with uniform heat generation per unit volume, q_g''' and with the surface temperature maintained at t_s, derive an expression for the temperature distribution in the cylinder in the following form:

$$t = t_s + \frac{q_g''' R^2}{4k}\left[1 - \left(\frac{r}{R}\right)^2\right]$$

where, k is thermal conductivity of the cylinder material, t is the temperature at a radial distance, r from the centre line.
If the solid cylinder is kept in a convective environment with average heat transfer coefficient, h and ambient temperature, t_a, show that the temperature distribution can be expressed in the following form: 20

$$t = t_\alpha + \frac{q_g''' R}{2h} + \frac{q_g''' R^2}{4k}\left[1 - \left(\frac{r}{R}\right)^2\right]$$

(b) A 66 kV transmission line carrying a current of 900 ampere and having a diameter of 10 mm is laid in a convective environment of 10 W/m^2-K and 35 °C. The thermal conductivity and electrical resistivity of the line material are 380 W/m-K and 1.75×10^{-6} Ω-cm. Calculate the following: 10

(i) The heat generation per unit volume.
(ii) The surface temperature of the line.
(iii) The maximum temperature in the line.

(c) Calculate the heat lost from a 60 W incandescent bulb whose surface temperature is 100 °C. The bulb is placed in a quiescent ambient air at 30 °C. Assume the bulb is a sphere of radius 25 mm. Neglect radiation heat transfer. The relevant correlation is

$$\overline{Nu} = 0.6\mathrm{Ra}^{0.25}$$

The thermo-physical properties at film temperature are as under:
k = 0.029 W/m-K; $\nu = 18.5 \times 10^{-6}$ m^2/s; Pr = 0.69 Take g = 9.80 m/s^2. 10

4. (a) (i) Using the concept of reversible cycle, show that the change of entropy during a thermodynamic process can be expressed as 7

$$S_2 - S_1 = \int_1^2 \left(\frac{\delta q}{T}\right)_R$$

(ii) Show that, during an irreversible process, the change of entropy is greater than

$$\int_1^2 \left(\frac{\delta q}{T}\right)$$

Hence, show that the change of entropy for irreversible adiabatic process is always positive and that of reversible adiabatic process is isentropic. 8

(b) Discuss the variables affecting engine performance of a spark ignition engine with the help of qualitative performance curves. 10

(c) Dry saturated steam at a pressure of 0.5 bar (saturation temperature is 32.76 °C) at the rate of 40000 kg/hr is to be condensed in a single-pass condenser. The cooling water enters the tubes at 20 °C and leaves at 26 °C. The tubes having inner and outer diameters of 25 mm and 27.5 mm respectively, are made of material with thermal conductivity of 110 W/m-K. If water and steam side coefficients are 5000 W/m^2-K and 10000 W/m^2-K respectively, estimate the number of tubes required, each having a length of 3 m. Take latent heat of steam at 0.5 bar as 2424 kJ/kg. Neglect fouling resistance. 15

SECTION—B

5. Answer any four parts:

(a) Discuss the parameters that affect the performance of vapor compression refrigeration system. 10

(b) Discuss the factors that affect the stage pressure ratio in an axial flow compressor. 10

(c) With the help of a sketch, discuss the governing of reheat steam turbine. 10

(d) "The essential requirement of steam drum is to ensure moisture free steam going to the superheater and bubble free water going to downcomer of a boiler." What is the reason behind this fact and how is it achieved in steam drum? 10

(e) For normal shock wave in an ideal gas, prove that

$$\frac{P_y}{P_x} = \frac{M_y}{M_x}\left[\frac{1+\frac{\gamma-1}{2}M_x^2}{1+\frac{\gamma-1}{2}M_y^2}\right]$$

where stations x and y represent the condition before and after shock wave. 10

6. (a) The evaporation and condensation temperatures of a 20 tons refrigeration plant are –8 °C and 30 °C respectively. The refrigerant is superheated to –2 °C before leaving the evaporator coil and the compression process is assumed to be isentropic. The refrigerant is sub-cooled by 5 °C before it enters the expansion valve. The compressor is double-cylinder, single-acting with the stroke is 1.5 times the bore. Work out the following:

(i) Sketch the vapor compression cycle on P-H and T-S diagrams
(ii) Mass flow rate of refrigerant in kg/min
(iii) Theoretical power input to compressor
(iv) Theoretical coefficient of performance
(v) Theoretical piston displacement
(vi) Theoretical bore and stroke
(vii) Volumetric efficiency of compressor, if clearance volume is 2%.

Use the following table. Symbols have usual meanings. The compressor runs at 1000 r.p.m.:

t	P	v	h_f	h_g	s_f	s_g	C_{Pl}	C_{Pg}
°C	bar	m^3/kg	kJ/kg		kJ/kg-K		kJ/kg-K	
–8	2.35	0.08	28.72	184.67	0.1149	0.1149	–	0.610
30	7.45	0.02	64.59	199.62	0.2400	0.2400	1.235	0.733

(b) With the help of neat sketch, discuss the working of a central air-conditioning system with controls. 15

7. (a) In an open-cycle gas turbine plant, the air is compressed in an axial flow compressor from inlet air temperature 288 K and pressure 1 bar to compressor pressure ratio 15. The same air is then heated to a maximum permissible temperature of 1700 K first in a heat exchanger (regenerator) by gas turbine exhaust which is 75% efficient and then in a combustion chamber. The same air at 1700 K is expanded in two stages turbines such that the expansion work is the

minimum. The air is then reheated in a reheated up to 1600 K after the high pressure stage. The isentropic efficiency of compressor and turbine may be taken as 87% and 88% respectively. The mechanical efficiency of compressor and turbine, each is equal to 99%. The combustor and generator efficiency, each is equal to 98%. Work out the following: 20

(i) Draw the system and show the process on T-S diagram.
(ii) Calculate the cycle thermal efficiency, work ratio and the net shaft work per kg of air.
(iii) Calculate the flow rate of air for an output of 250 MW and specific fuel consumption if lower calorific value of fuel is 42 MJ / kg.

Take: $\gamma = 1.4$, $C_P = 1.005$ kJ / kg-K for air.

(b) An axial flow compressor consists of eighteen stages. The stagnation compressor pressure ratio achieved in the compressor is 20 : 1 with a stagnation isentropic efficiency of 0.88. The stagnation pressure and temperature at the inlet are 1 bar and 20 °C respectively. The work is divided equally between the stages. The mean blade velocity is 200 m / s and 50% reaction is used. The flow velocity through the compressor may be assumed constant and equal to 120 m/s. Work out the following: 20

(i) Draw the system, inlet and outlet velocity triangles, and show the process on T-S diagram.
(ii) Calculate the blade angles.
(iii) Calculate the power required to drive the compressor if mass flow rate is 500 kg/s and mechanical efficiency is 98%.
(iv) Draw a normal standard performance curve for an axial flow compressor.

8. (a) A power station is to be built to meet the following electrical load requirements:

Time (hours):	0-6	6-12	12-14	14-18	18-20	20-24
Load (MW) :	250	750	500	900	400	300

Work out the following: 20

(i) Select the suitable generating units to meet the requirements.
(ii) Draw the load curve, load duration curve and explain them in brief.
(iii) Calculate the load factor, plant capacity and plant capacity factor. Also comment on the results with reference to modern power plant.

(b) With the help of a sketch, discuss the working principle of electrostatic precipitator for collecting fly ash particle in a pulverized coal-based steam power plant. 10

(c) With the help of a simple sketch, discuss the working principle of attemperator to control the steam temperature in boiler. 10