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.

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SECTION 'A'

1. Answer any *four* of the following:

(a) What are the various types of dislocations? Explain any two of them with the help of sketches. What is interstitial free steel and where is it used. 10

(b) (i) Show that the cycloidal or the involute shape for profiles of wheel teeth satisfy the fundamental condition for the transmission of uniform motion.

(ii) What are the principal advantages of the involute shape over cycloidal shape of gear tooth? 10

(c) Two rigid bodies 'A' and 'B' turn about fixed parallel axes and 'A' drives 'B' by direct contact. Show that the ratio of angular velocity of B to that of A can only be constant, if contact surfaces are so shaped that the normal at the point of contact intersects the line of centres at a fixed point. 10

(d) What is deep drawing process for sheet metal forming?
Explain the function of a blank holder. What is drawing ratio and how is the drawing ratio increased? 10

(e) Construct Shear Force and Bending Moment diagrams for a beam as shown in Figure 1. The loading is shown in the diagram. 10

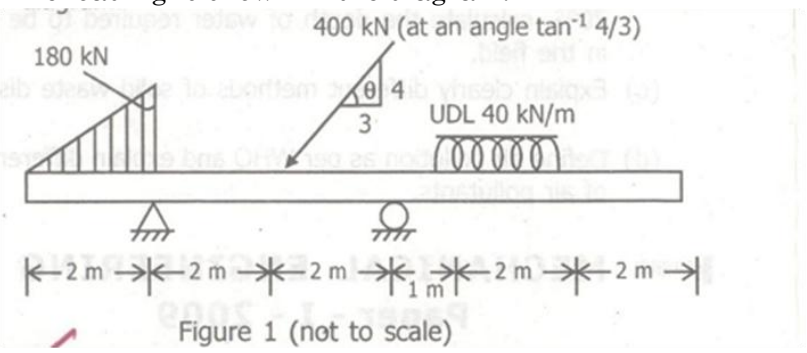

Figure 1 (not to scale)

2. (a) In a compound helical spring the inner spring is arranged within and concentric with the outer one but is 15 mm shorter. The outer spring has 12 coils of mean diameter 30 mm and the diameter of wire is 3 mm. Find the stiffness of the inner spring is an axial load of 120 N causes the outer one to compress 25 mm. If the vertical clearance between the two springs is to be 2 mm, find the diameter of the wire of the inner spring when it has 8 coils. Take G = 80 GPa for both springs. 15

(b) In a two-dimensional stress system, normal stresses of 30 MPa and 100 MPa act on two mutually perpendicular planes in conjunction with a shear stress of 40 MPa. The stress intensity, judged by the distortion energy, is excessive. As it was found impossible to reduce the applied stresses, the severity of the distortion energy condition was reduced by increasing the normal stress of 30 MPa to have higher value, S. Find the value of S at which the distortion energy minimum. 15

(c) A straight bar of alloy 1 m long and 12 mm × 6 mm in section is loaded as a column till it buckles. Assuming Euler formula for pinned-ends to apply, estimate the maximum central deflection before the material attains its yield point, at 260 MPa. E = 80 GN/m^2. 10

3. (a) A 40 mm diameter shaft 2.5 m long has a mass of 1 kg/ meter length. It is simply supported at the ends and carries three masses 90 kg, 140 kg and 60 kg at a distance of 1.7 m, 1.0 m, and 0.5 m respectively from right support. Taking E = 20 GN/m^2, find the frequency of transverse vibrations. 15

(b) A revolving mass of a scooter engine crank is 2 kg at a radius of 10 cm. Determine the magnitude of balance mass at a radius of 100 mm in two planes 10 cm apart. One of the planes is at a distance of 5 cm from the plane of the crank. These planes are

(i) on same side of crank
(ii) on opposite sides of crank. 15

(c) How do the following parameters affect the pressure angle in a cam follower combination?

(i) Steepness of displacement diagram
(ii) Base circle radius
(iii) Follower displacement

Justify your answer. 10

4. (a) "Composite material is a generic term." Explain this statement. Explain also the terms 'law of mixtures', 'wetting', and 'debonding' as applied to composite materials. What are the main constituents of a grinding wheel? 20

(b) Distinguish between grain boundary movement during cooling and heating and grain distortion during metal deformation during extrusion. Give two products/examples where there are no grain boundaries and what properties are enhanced as a result of absence of grain boundaries. 20

SECTION 'B'

5. Answer any *four* of the following:

(a) What are 'G' codes and W codes?
To make a 175 mm dia hole in a mild steel plate of thickness 5 mm, with the surface finish of the finished hole to have a value of 20 microns, choose suitable machine tools to carry out this operation. Give the process plan. 10

(b) Two plates of aluminum and stainless steel are to be welded back to back to create a single plate of thickness equal to the sum of the thickness of the two plates. Suggest the suitable process and explain it in brief. 10

(c) What is the common composition of the electrolyte used in ECM process? What is the wear on the electrode for making a 5 mm dia 50 mm deep blind hole in a plate of stainless steel by ECM? What will be the tool wear, if instead of ECM, we use EDM process? 10

(d) How does Value Engineering differ from Value Analysis? Define value. Explain the different types of values with the help of suitable examples. 10

(e) Define Material Requirement Planning (MRP). What are its objectives? Explain the following terms associated with MRP:

(i) Dependent demand
(ii) Lot size
(iii) Time phasing
(iv) Gross requirements
(v) Net requirements 10

6. (a) With the help of Taylor's tool life equation, determine the shape of the curve between velocity of cutting and life of the tool. Assume an HSS tool and mild steel as work material. 10

(b) Where do you use gauges instead of micrometers for the control of dimensions of machined parts? Set gauges for the shaft of size 100 ± 1 mm. and a bush with a hole size of 100 ± 1 mm. Can these gauges be used if the tolerances are changed to ± 1.2 mm? 10

(c) Casting is a process which gives the products with isotropic properties. Justify why the castings are subjected to the forging process and the resulting change in some properties of the product. Name these properties and give examples of forgings where these properties are absolutely essential. 20

7. (a) What is sales forecasting? Explain why a sales forecast is required. The past data about the load on a machine centre is as follows:

Month	Load in machine-hours
1	585
2	611
3	656
4	748
5	863
6	914
7	964

(i) Compute the forecast of the load on the centre in the 8th month, using a five month moving average.

(ii) Compute a weighted three month moving average for the 8th month, where the weights are 0.5 for the latest month, 0.3 and 0.2 for the other months, respectively. 10

(b) 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 and free slacks of all the jobs. 15

(c) What is a line balancing problem? Explain the following terms related with line balancing: Minimum rational work element Total work content Workstation process time Cycle time Precedence diagram Balance delay. 15

8. (a) Draw flow chart to find the diameter of a solid steel shaft, using 'C' language, to transmit a given power at a specified speed. The ultimate tensile strength of steel and factor of safety are also given. 15

(b) What is a transportation problem? Solve the following assignment problem, in which the figures in the matrix represent unit cost of production of each component. What is the minimum cost? 15

		Component				
		1	2	3	4	5
Machine	A	11	17	8	16	20
	B	9	7	12	6	15
	C	13	16	15	12	16
	D	21	24	17	28	26
	E	14	10	12	11	15

(c) Why and how is a queue formed?

A store employs one cashier at its counter. On an average 10 customers arrive in 5 minutes while the cashier can serve 12 customers in the same time. Assuming Poisson distribution for arrival and exponential distribution for service rate, find the average number of units in the system, the average length of the waiting line, expected time a customer spends in the system, expected time a customer spends in the queue. 10

MECHANICAL ENGINEERING Paper II

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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) With the help of Maxwell's relations, prove that Joule-Thomson coefficient μ_j of a gas is given by

$$\mu_j = \left[\frac{\partial T}{\partial p}\right]_h = \frac{T^2}{C_p}\left[\frac{\partial}{\partial T}\left(\frac{v}{T}\right)\right]_p$$

What does this equation signify? 10

(b) Discuss the functions of intake and exhaust systems of an SI engine with their design objectives and sketches. 10

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

(d) (i) Define thermal boundary layer and show its distribution over a flat plate. 5

(ii) Prove Reynolds' analogy with reference to turbulent flow as given below: 5

$$St_x = \frac{C_{fx}}{2}$$

(e) Bring out the various psychrometric processes that are shown on a psychrometric chart and give a simple sketch of each system to achieve it. 10

2. (a) 100 kg/s of steam enters a steam turbine at an enthalpy of 3250 kJ/kg and a velocity of 160 m/s. The steam comes out at an enthalpy of 2640 kJ/kg with a velocity of 100 m/s. At steady-state condition, the turbine develops work equal to 55 MW. Heat transfer between the turbine and surroundings occurs at an average outer temperature of 350 K. The entropy of steam at inlet and exit of the turbine are 6.93 kJ/kg-K and 7.35 kJ/kg-K respectively. Neglect the changes in potential and kinetic energy between inlet and outlet. Work out the following:

(i) Draw the system with control volume and show the processes on p-v and T-s diagrams.

(ii) The rate at which entropy is produced within the turbine per kg of steam flowing.

(iii) Suggest methods to improve the performance of the steam turbine. 20

(b) A satellite incorporates a reversible heat engine which operates between a hot reservoir at T_1 and a radiating panel at T_2. The radiation from the panel is given

by $Q_2 = kAT_2^4$, where k is Stefan-Boltzmann constant and A is the area of the panel. Work out the following:

(i) Draw the system under given conditions

(ii) Prove that the area of the panel for a given work output and a value of T_1 will be minimum when $T_2/T_1 = 3/4$.

(iii) Further, prove that the minimum area of the panel will be given by

$$A_{\min} = \frac{256W}{27kT_1^4}$$

where W is the output of the engine. 20

3. (a) In a simple carburetor, the petrol in the float chamber stands 6 mm below the jet opening. The engine consumes 6.4 kg fuel/h. The fuel jet diameter is 1.25 mm and the discharge coefficient of the fuel orifice is 0.64. If the air-fuel ratio is 16 : 1, estimate –

(i) the air velocity at the throat;

(ii) the throat diameter;

(iii) the pressure drop in cm of water.

The coefficient of discharge for air is 0.85 and the ambient conditions are pressure = 1 bar and temperature = 288 K. Take the density of fuel and air as 770 kg/m^3 and 1.1122 kg/m^3 respectively. Neglect compressibility effect. 20

(b) A four-cylinder petrol - fueled car is to be converted to run on (i) CNG and (ii) hydrogen. Draw schematic diagrams indicating the changes required for conversion in each case. Justify your answer on the basis of the properties of the fuels. 20

4. (a) For some high degree of research work in the field of medicine, liquid nitrogen is stored in a spherical thin-walled metallic container at 100 K. The container has a diameter of 0.8 m and is covered with an evacuated reflective insulation composed of silica powder (K = 0.0017 W/m-K). The insulation is 35 mm thick and the outer surface is exposed to ambient air at 30 °C. The convective heat transfer coefficient between ambient air and insulation is 20 W/m^2-K. The latent heat of vaporization and the density of liquid nitrogen are 200 kJ/kg and 805 kg/m^3 respectively. Work out the following:

(i) Sketch the system and thermal circuit, and write the assumptions made.

(ii) The rate of heat transfer to the liquid nitrogen.

(iii) The rate of liquid boil-off and the loss per day. 20

(b) With the help of a suitable diagram, explain the purpose of cascading vapour compression refrigeration systems.

In an ammonia vapour refrigeration plant, the pressure range is from 3.15 bar in the evaporator to 10.5 bar in the condenser, the compression is isentropic and before entering the throttle valve the refrigerant ammonia is sub-cooled. The temperatures of the refrigerant at entry and exit from the condenser are 50°C and 20°C respectively, and the water being circulated in the condenser at the rate of 10.5 kg/min has a temperature rise of 10°C. The compressor unit is single-cylinder, single-acting with bore10 cm, stroke 15 cm while running at 200 rev/min having an indicated mean effective pressure equal to 35 bar. If the plant produces 50 kg/h of ice at 0 °C from water at 15°C, determine (i) COP, (ii) flow rate of refrigerant and (iii) condition of vapour at entry to the compressor.

Take latent heat of ice as 335 kJ/kg. The relevant properties of ammonia are as follows: 20

Pressure	Saturation temperature	Enthalpy (kJ/kg)		Specific heat (kJ/kg-K)	
(bar)	(K)	Liquid	Vapour	Liquid	Vapour
315	264	–35.6	1264	-	-
10-5	304	134	1294	4.6	2.8

SECTION—B

5. Answer any *four* parts:

(a) Discuss the stalling phenomena in an axial flow compressor and write its effects on the performance. 10

(b) Define Fanno and Rayleigh lines with reference to normal shock wave. Show these lines on h-s diagram for subsonic, sonic and supersonic conditions. Give the physical meaning of these lines. 10

(c) With the help of a sketch, discuss the working principle of a pulverized coal direct-firing system of a steam power plant. 10

(d) With the help of sketch, discuss the working principle of bubbling fluidized-bed boiler. 10

(e) Discuss the need of governing of steam turbines. With the help of a sketch, discuss the working principle of a hydro-mechanical speed-governing loop. 10

6. (a) In a solar water-heating system, a flat-plate solar collector with no cover plate is used to collect the solar radiation to heat water. The surface emissivity of the absorber is 0.15 while the solar absorptivity is 0.96. At a given time of the day, the absorber temperature is 120 °C when the solar irradiation is 800 W/m^2, the effective sky temperature is –6 °C. The ambient temperature is 27 °C. Assume that the heat transfer convection coefficient for the calm dry condition is given by

$$h = 0.23\,(T_S - T_\infty)^{1/3}\ \text{W/m}^2\text{-K}$$

Assume steady-state condition, bottom surface is well-insulated and the absorber surface is diffused. Work out the following:

(i) Sketch the system and its control volume

(ii) The useful heat removal rate in W/m2 from the collector

(iii) The efficiency of the collector

(iv) State effect on collector efficiency with reasoning, if the cover plate is installed. 20

(b) (i) For an office of 6m × 3m × 4m size, the inside and outside conditions are dbt = 22°C, φ = 55% (h = 45 kJ/kg) and dbt = 40 °C, wbt = 26 °C (h = 80.5 kJ/kg and v = 0.94 m^3/kg of dry air) respectively. Further, it may be presumed that the office has structural load of 6000 kJ/h, 5 tube lights each of 40 W ratings, 13.5 air changes per 24 hour for the infiltration load, 71 × 10^{-1} m^3/s per person of ventilation, 10 persons occupancy and each occupant releases 500 kJ/h.

Work out the capacity of a window air-conditioner that will suffice to achieve the desired objective. 10

(ii) A steam power plant employs a wet type cooling tower which receives warm water at 30 °C at the rate of l.2 kg per kg of air. Air enters the tower at the dbt of 20 °C and relative humidity of 60% and leaves it at a dbt of 28 °C and 90% relative humidity. Make-up water is added at 20 °C. Calculate -

(i) the temperature of water leaving the tower;

(ii) the approach and range of the cooling tower;

(iii) the fraction of water evaporated.

For inlet (1) and outlet (2) air

twb_1 = 15.2 °C

twb_2 = 26.7 °C

h_1 = 43 kJ/kg dry air

h_2 = 83.5 kJ/kg dry air

w_1 = 0.00881 kg water vapour/kg dry air

w_2 = 0.02132 kg water vapour/kg dry air

h_v = 84 kJ/kg 10

7. (a) An industrial centrifugal compressor running at 9000 r.p.m. delivers 650 m^3/min of free air. The air is compressed from 1 bar and 30 °C to a pressure ratio of 4.5 with an isentropic efficiency of 0.86. Blades are radial at outlet and the flow velocity of 70 m/s may be assumed throughout constant. The outer radius of impeller is twice the inner and the slip factor may be assumed as 0.92. At inlet, the blade area coefficient may be taken as 0.95. Work out the following:

(i) Draw the system and show the compression process on h-s diagram. Also, draw velocity diagrams
(ii) The final temperature of air
(iii) The power input to compressor, if mechanical efficiency is 0.95
(iv) The impeller diameter at inlet and outlet
(v) The breadth of impeller at inlet
(vi) The impeller blade angle at inlet 20

(b) A 15-stage 50% reaction turbine develops a diagram power of 10 M W. The inlet condition of steam is at 15 bar, 350 °C, while the condenser pressure is 0.14 bar. The stage efficiency is 75% for each stage and the reheat factor is 1.04. At a certain stage, the steam is at 1 bar, dry saturated. The exit angle of the blades is 20° and the blade velocity ratio is 0.7. The blade height may be taken as 1/12 of the mean blade diameter. Work out the following:
(i) The flow rate of steam required, assuming that all the stages develop equal work
(ii) The mean blade diameter
(iii) The speed of the rotor
(iv) Sketch the system and velocity diagrams, and show the process on h-s diagram

Given that enthalpy drop (from Mollier chart) = 855 kJ/kg.
At 1 bar, v_g = 1.694 m^3/kg. 20

8. (a) Draw a labeled schematic diagram of a modern radiant power boiler with natural circulation. Clearly show (i) boiler drum (ii) various accessories, (iii) primary air and secondary air supply systems, and (iv) feedwater system. How is the balance draft created? Explain. 20

(b) Differentiate between a base load and a peak load power plant. Explain with suitable examples. A power plant caters to a peak load of 160 MW. It has an annual load factor of 0.85, capacity factor of 0.8 and use factor of 0.82. Calculate:
(i) the annual energy produced;
(ii) reserve capacity over and above the peak load;
(iii) hours during which the plant is not in service per year;
(iv) annual revenue earned, if the energy is sold at Rs 3 per kW. 20