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. (a) A slider-crank reciprocating mechanism has the following data :
Radius of the crank = 480 mm
Length of the connecting rod = 1600 mm
Angular velocity of the crank = 20 rad/s
Find the velocity and acceleration of the piston for the crank position of $\theta = 45°$ from the inner dead centre. 8

(b) Two pulleys having diameters 640 mm and 480 mm, are used to connect two parallel shafts by a crossed belt drive. The distance between the centre lines of the shafts is 3 m. Determine how much the length of the belt should be changed, if it is desired to alter the direction of rotation of the driven shaft. 8

(c) A rod of 1 m length is kept at a temperature of 30°C. Find the expansion of the rod when the temperature is raised to 80°C. If this expansion is prevented, find the stress induced in the material of the rod.
Take $E = 100$ GPa and $\alpha = 0.000012$/°C. 8

(d) The state of stress at a point in a loaded piece of material is given by
$\sigma_x = 85$ kPa, $\sigma_y = -40$ kPa and $\tau_{xy} = \pm 50$ kPa.
Find the magnitudes of the principal stresses. Also find the magnitude of the maximum shear stress and the plane on which this acts. 8

(e) In a simple cubic crystal, draw the following planes : 8
(i) (110)
(ii) (111)

2. (a) (i) State the law of gearing. Also state the condition to meet the above requirement. Name the forms of teeth profiles normally used to avoid interference between the mating gears.
(ii) A pair of pinion and gear of 20° pressure angle involute profiles mesh externally and provide a velocity ratio of 3. The addendum is equal to 1.12 of module. Determine the minimum number of teeth on each to avoid interference. 5+10

(b) A thick cylinder is made of 6 cm internal diameter. It is subjected to an internal

pressure of 50 MPa. If the maximum tensile stress is limited to 100 MPa, find the thickness required. Also, show the variations of hoop and radial stresses across the thickness of the cylinder. 15

(c) Draw a neat and clean iron-carbon equilibrium diagram and label its various features. 10

3. (a) A single cylinder reciprocating engine has the following data :

Mass of reciprocating parts = 40 kg
Mass of revolving parts = 36 kg at crank radius
Speed of crank = 150 rpm
Stroke length of reciprocating parts = 350 mm

All the revolving parts and 60% of the reciprocating parts need to be balanced. Determine:

(i) Balancing mass required at a radius of 340 mm
(ii) Unbalanced force when the crank has turned 45° from the top dead centre 10

(b) A machine mounted on 4 springs and fitted with a dashpot has a mass of 120 kg. The stiffness of each spring is 18 N/mm. The amplitude of vibrations reduces from 33.75 mm to 6 mm in two complete oscillations. Assuming that the damping force varies as the velocity, determine

(i) damping coefficient, and
(ii) ratio of frequencies of damped and undamped vibrations. 10

(c) A uniform beam (I = 7,800 cm^4) is 6 m long and carries a central concentrated load of 60 kN. Taking E = 210 GPa, calculate the deflection under the load if the beam is built-in at one end and simply supported at the other end. 10

(d) Draw the heating cycle on Temperature - Time scale of the following processes: 10

(i) Process annealing or Subcritical annealing
(ii) Spheroidize annealing
(iii) Austempering

4. (a) Each arm of a Porter governor is 200 mm long and is pivoted on the axis of the governor. The radii of rotation of the balls at the maximum and minimum speeds are 160 mm and 120 mm respectively. The mass of each ball is 4 kg and the mass of sleeve is 24 kg. Determine the range of speed of this governor. Also find the range of speed, if the friction at the sleeve is 18 N. 10

(b) A shaft is required to transmit 40 kW at 300 r.p.m. The maximum torque may be 1.5 times the mean torque. The allowable twist is 1° per m length of the shaft. Determine the diameter of the solid shaft. 10

(c) A column of 6 m length is fixed at both ends. It is of rectangular cross-section of 20 cm × 10 cm. Determine the Euler's crippling load on the column, if E = 200 GPa. 10

(d) Determine the composition, in atom percent, of an alloy that consists of 97 wt% aluminium and 3 wt% copper. 10

SECTION—B

5. (a) Explain the variables influencing machinability. How is machinability assessed? 8

(b) Determine the material removal rate and the electrode feed rate in the

electrochemical machining of an iron surface that is 10 mm × 10 mm in cross-section, using NaCl in water as electrolyte. The gap between the tool and workpiece is 0.25 mm. The supply voltage is 12 V DC. The specific resistance of the electrolyte is 4 Ω cm. For iron, atomic weight = 55.85, valency z = 2 and density ρ_a = 7860 kg/m^3. 8

(c) Enlist the areas of project monitoring. What are the steps for project monitoring? 8

(d) An analysis of a company reveals the following sales and cost information :
Current capacity = 1,00,000 units
At current level of operations, its margin of safety is 5% of its break-even point, whereas contribution margin P/V ratio is 25% and unutilised capacity is 10,000 units. For the sale price of Rs 40 per unit, determine the following : 8
(i) Break-even point in sales volume
(ii) Fixed costs
(iii) Variable costs per unit
(iv) Margin of safety in units

(e) Define ROM, PROM, EPROM, EEPROM and RAM. 8

6. (a) During orthogonal turning operation of a medium carbon steel rod with a carbide tool having orthogonal rake angle 10°, the following observations were made:
Width of the chip = 6 mm
Uncut chip thickness = 0.1 mm
Chip thickness ratio = 0.4
Horizontal component of cutting force = 1300 N
Vertical component of cutting force = 1650 N
Determine the component of cutting force along the rake face and shear plane. Also find out coefficient of friction, resultant force and shear stress. 15

(b) Explain the features and policy guidelines for ABC analysis. A manufacturer has to supply his customer 3600 units of his product per year. Shortages are not permitted. Inventory carrying cost amounts to Rs 1.2 per unit per annum. The set-up cost per run is Rs 80. Compute the following: 15
(i) Economic order quantity
(ii) Optimum number of orders per annum
(iii) Average annual inventory cost (minimum)
(iv) Optimum period of supply per optimum order

(c) Draw a flow chart for computation of simple interest for 3 sets of p, n, r. 10

7. (a) While turning a mild steel rod with a HSS cutting tool at a feed of 03 mm/rev. and depth of cut of 3 mm, the following observations were made :

Cutting velocity	V, m/min	20	30
Tool life	T, min	70	40

Determine the cutting velocity, if desired tool life is 60 minutes. 10

(b) A cylindrical pipe of mild steel with inside diameter 60 mm and thickness 2.5 mm is to be reduced down to 48 mm and thickness 1.75 mm. Consider die angle as 40° and coefficient of friction is 0.1. Compare the pipe drawing force on cylindrical plug and movable mandrel. 10

(c) A company intends to buy a machine having a capacity to produce 1,70,000 quality parts per annum. The machine constitutes a part of the total product

line. The system efficiency of the product line is 85%.

(i) Find the system capacity per hour.

(ii) The time required to produce each part is 100 seconds and the machine works for 2000 hours per year. If the utilization of the machine is 60% and the efficiency of the machine is 90%, compute the output of the machine per hour.

(iii) Calculate the number of machines required. 10

(d) A linear programming problem is given subjected to the constraints

$5x_1 + x_2 \geq 10$

$x_1 + x_2 \geq 6$

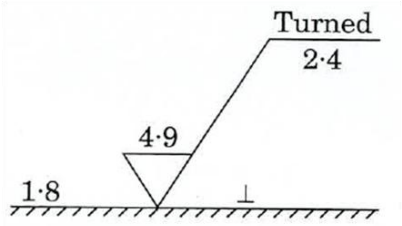
$x_1 + 4x_2 \geq 12$

$x_1, x_2 \geq 0$

For minimization of the function $z = 3x_1 + 2x_2$, plot each constraint on a graph paper and show the feasible region. 10

8. (a) (i) Determine the dimensions of 'Go' and 'No Go' gauges of a plug gauge for checking 75 ± 0.05 mm diameter holes. Show the dimensions using Bilateral and Unilateral systems. Consider gauge maker's tolerance as 10% of work tolerance. 10

(ii) What information can you obtain from the following surface roughness representation? 5



(b) A small project is composed of 7 activities whose time estimates are listed in the table below. Activities are identified by their beginning (i) and ending (j) node numbers.

Activity	Estimated duration (in weeks)		
(i-j)	Optimistic	Most likely	Pessimistic
1-2	1	1	7
1-3	1	4	7
1-4	2	2	8
2-5	1	1	1
3-5	2	5	14
4-6	2	5	8
5-6	3	6	15

(i) Draw the network diagram and critical path.

(ii) Find the expected duration and variance for each activity.

(iii) Find the expected project length. 15

(c) Write a C-program using Array to find out the average marks obtained by a class of 50 students in a test conducted. 10

MECHANICAL ENGINEERING Paper—II

Time Allowed: Three Hours *Maximum Marks: 200*

QUESTION PAPER SPECIFIC INSTRUCTIONS

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Assume suitable data, if necessary and indicate the same clearly.
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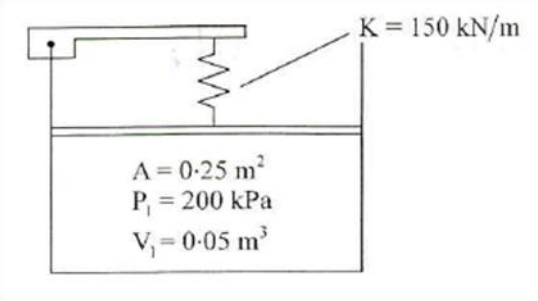
Newton may be converted to kgf using the equality 1 kilonewton (1 kN) = 100 kgf, if found necessary.
All answers should be in SI units.
Take: 1 kcal = 4.187 kJ and 1 kg/cm^2 = 0.98 bar
1 bar = 10^5 pascals
Universal gas constant = 8314.6 J/kmol-K
Psychrometric chart is enclosed.

SECTION—A

1. (a)



A piston-cylinder device contains 0.05 m^3 of a gas initially at 200 kPa. At this state, a linear spring that has a spring constant of 150 kN/m is touching the piston but exerting no force on it. Now heat is transferred to the gas, causing the piston to rise and to compress the spring until the volume inside the cylinder doubles. If the cross- sectional area of the piston is 0.25 m^2, determine (i) the final pressure inside the cylinder, (ii) the total work done by the gas. 10

(b) Calculate the approximate Grashof number and state if the flow is laminar or turbulent for the following :

(i) A central heating radiator, 0-6 m high with a surface temperature of 75°C in a room at 18°C, ρ = 1.2 kg/m^3, P_r = 0.72 and $\mu = 1.8 \times 10^{-5}$ kg/ms.

(ii) A horizontal oil sump with a surface temperature of 40°C, 0-4 m long and 0-2 m wide containing oil at 75°C. Take ρ = 854 kg/m^3, P_r =

546, $\beta = 0.7 \times 10^{-3}\ K^{-1}$ and $\mu = 1.8 \times 10^{-5}$ kg/ms. 10

(c) Discuss the causes, effects and the actions to be taken to remove/reduce the following emissions from I.C. engines :

(i) Oxides of Nitrogen (NO_x)

(ii) Smoke

(iii) Carbon Monoxide (CO)

(iv) Unburned Hydrocarbons (HC)

(v) Sulphur Oxides (SO_2) 10

(d) A chimney has a height of 100 metres. For the maximum discharge condition, calculate the temperature of the chimney gases and the draught produced if the air supplied per kg of fuel is 18 kg. Also determine the efficiency of this chimney as an instrument for creating the draught, if the temperature of chimney gases in artificial draught system is limited to 120°C. Take the boiler house temperature as 40°C and the specific heat of flue gases as 1.005 kj/kg K. 10

2. (a) A four-cylinder four-stroke S.I. engine with 80 mm bore and 90 mm stroke, runs at 4000 rpm and uses a fuel having 84% carbon and 16% hydrogen by mass. The volumetric efficiency of the engine at that speed is 80%. The ambient conditions are: pressure = 1.0 bar, temperature = 25°C. The depression at the venturi throat is 0.06 bar. The actual quantity of air supplied is 0.95 of the stoichiometric value. Calculate the fuel flow rate, the air velocity at the throat and the throat diameter.

Take: R(air) = 287 J/(kg K), R(fuel vapour) = 98 J/(kg K)

C_p = 1005 J/(kg K), γ = 1.4 and coefficient of discharge at venturi throat as 1. 20

(b) A counterflow, concentric tube heat exchanger is used to cool the lubricating oil for a large industrial gas turbine engine. The flow rate of cooling water through the inner tube (D_i = 25 mm) is 0.2 kg/s, while the flow rate of oil through the outer annulus (D_0 = 45 mm) is 0.1 kg/s. The oil and water enter at temperature of 100 and 30°C respectively. How long must the tube be made if outlet temperature of the oil is to be 60°C? State assumptions made, if any. Comment on the magnitude of length of tube. 20

Properties of Oil

Temperature	C_p	μ	K	Pr
°C	J/kgK	N.s/m²	W/mK	
100	2250	1.41×10^{-2}	0.137	300
80	2131	3.25×10^{-2}	0.138	546
60	2035	8.36×10^{-2}	0.141	1205

Properties of Water

Temperature	C_p	μ	K	Pr
°C	J/kgK	N.s/m²	W/mK	
30	4178	769×10^{-6}	0.620	5.20
35	4178	725×10^{-6}	0.625	4.85
40	4179	631×10^{-6}	0.634	4.16

Nusselt number for fully developed laminar flow in a circular tube annulus with one surface insulated and the other at constant temperature:

D_i/D_0	Nu_i	Nu_0	D_i/D_0	Nu_i	Nu_0
0	-	3.66	0.25	7.37	4.23

0.05	17.46	4.06	0.50	5.74	4.43
0.10	11.56	4.11	≈1.00	4.86	4.86

3. (a) The output of a three stage gas turbine is 30 MW at the shaft coupling at an entry temperature of 1500 K. The overall pressure ratio across the turbine is 11 and efficiency 88%. If the pressure ratio of each stage is same, determine:

(i) pressure ratio of each stage
(ii) polytropic efficiency
(iii) the mass flow rate
(iv) the efficiency and power of each stage

The properties of the working medium are the same as of air ($\gamma = 1.4$, $C_p = 1.005$ kJ/kg K). Assume an efficiency of 91% to take into account shaft losses due to disc and bearing friction. 20

(b) A retail shop located in a city at 30° N latitude has the loads as given below :

Room Sensible heat – 58.15 kW
Room Latent heat – 14.54 kW

The summer outside and inside design conditions are :

Outside : 40°C DB, 27°C WB
Inside : 25°C DB, 50% RH

70 m^3/min of ventilation air is used. Determine the following :

(i) Ventilation load
(ii) Grand total heat
(iii) Effective sensible heat factor
(iv) Apparatus dew point
(v) Dehumidified air quantity
(vi) Condition of air entering and leaving apparatus

Given a choice, what bypass factor (BF) would you choose from 0.05, 0.1, 0.15, 0.20. Give justification for selection of BF. Solve the problem using BF of 0.15. Use of Psychrometric chart is permitted. 20

4. (a) Describe the working principle of Jerk type injection pump with the help of neat diagram. Show the position of the helix for various load conditions. 20

(b) In a reversed Carnot refrigerator system of 1TR cooling capacity running on perfect gas, heat is absorbed at –10°C and rejected at 50°C. Find the states at all the points of the cycle, mass flow rate, volume flow rates and COP. The maximum pressure ratio is 5 and the pressure at inlet to the isentropic process is standard atmospheric pressure. Take $C_p = 1.005$ kJ/kg K, R = 0-287 kJ/kg K and $\gamma = 1.4$. Plot the cycle on *p-v* and *T-s* diagrams. Comment on the area of *p-v* diagram. 20

SECTION 'B'

5. (a) A 3 cm OD pipe is to be covered with two layers of insulation, each having a thickness of 2.5 cm. The average thermal conductivity of one insulation is five times that of the other. Determine the percentage decrease in heat transfer if the better insulating material is next to the pipe than if it is the outer layer. Assume that the outside and inside surface temperatures of the composite insulation are fixed. 10

(b) Air is compressed steadily by a reversible compressor from an inlet state of 100 kPa and 300 K to an exit pressure of 900 kPa. Determine the compressor work

per unit mass for (i) Isentropic compression with $\gamma = 1.4$; (ii) Polytropic compression with $n = 1.3$; (iii) Isothermal compression and (iv) Ideal two-stage compression with intercooling with a polytropic exponent of 1.3. 10

(c) Discuss the effect of the following variables on ignition lag:
   (i) Nature of fuel and air/fuel ratio
   (ii) Initial temperature and pressure
   (iii) Spark timing
   (iv) Turbulence and engine speed
   (v) Gap between electrodes of the spark plug 10

(d) Determine the pressure ratio developed and the power required to drive a centrifugal compressor (impeller diameter = 45 cm) running at 7200 rpm. Take zero swirl at entry and $T_{01} = 288$ K. Assume isentropic flow with no shock, and radially tipped impeller blades. Take $C_p = 1.005$ kJ/kg K and $\gamma = 1.4$. 10

6. (a) A food compartment of a refrigerator is maintained at 4°C by removing heat from it at a rate of 360 kJ/min. If the required power input to the refrigerator is 2 kW, determine (i) the CO.P. of the refrigerator and (ii) the rate of heat rejection to the room that houses the refrigerator.
Also state the Kelvin Plank and Clausius statement being used for second law of thermodynamics. Further define CO.P. of refrigerator, C.O.P. of heat pump and show that

$$(\text{C.O.P.})_{\text{heat pump}} = 1 + (\text{C.O.P.})_{\text{refrigerator}}$$ 20

(b) The internal energy of a certain substance is expressed by the equation

$$u = 3.62\,pv + 86$$

where u is in kJ/kg, p in kPa and v is in m^3/kg.
A system composed of 5 kg of this substance expands from an initial pressure of 550 kPa and a volume of 0.25 m^3/kg to a final pressure of 125 kPa, in a process in which pressure and volume are related by $pv^{1.2}$ = constant. If the expansion process is quasistatic, determine work (W), change in internal energy and heat transferred in this process. 10

(c) The performance of an air-conditioner unit rated as 40 Tons, seems to be indicating poor cooling. The test on heat rejection to atmosphere in its condenser shows the following :

Cooling water flow	: 4 L/s
Water inlet temperature	: 30°C
Water outlet temperature	: 40°C
Power input to motor	: 40 kW
Efficiency of motor	: 95%
Specific heat of water	: 4.186 kJ/kgK

Calculate the actual refrigerating capacity of the unit and conclude on whether the unit is giving poor cooling. 10

7. (a) A four-cylinder S.I. engine has a bore of 60 mm and a stroke of 85 mm. It runs at 3000 rpm and is tested at this speed against a brake which has a torque arm of 0.35 m. The net brake load is 160 N and the fuel consumption is 6.6 lit/hr. The specific gravity of the fuel used is 0.78 and it has a lower calorific value of 44,000 kJ/kg. A Morse-test is carried out and the cylinders are cut out in the order 1, 2, 3, 4 with the corresponding brake loads of 114, 110, 112 and 116 N respectively. Calculate for this speed the bp, the bmep, the bte, the bsfc, the ip,

the mechanical efficiency and the imep. 20

(b) The temperature distribution across a wall, having thickness of 1 m, at an instant of time is given as:

$$T(x) = 900 - 300x - 50x^2$$

where T is in degree Celsius and x is in metres. The uniform heat generation of 1000 W/m^3 is present in the wall of area 10 m^2 having density ρ = 1600 kg/m^3, thermal conductivity k = 40 W/mk and specific heat C = 4 kJ/kg K.

Determine

(i) the rate of heat transfer entering the wall and leaving the wall,

(ii) the rate change of internal energy of the wall.

(iii) the time rate of temperature change at x = 0 and at x = 0.5 m. 20

8. (a) Steam is supplied by the steam generator at 90 bar and 500°C. After the expansion in the turbine to 10 bar a portion of the steam is bled for regenerative feed heating and the remaining is passed on to the reheater from where it returns to the turbine at 500°C. Expansion further continues to 0.07 bar. For 1 kg of mass of steam supplied at generator inlet, calculate (a) heat supplied, (b) heat rejected, (c) net work done, (d) thermal efficiency, and (e) steam rate in kg/kWh. Assume the specific volume of water as 0.001074 m^3/kg. Specific enthalpy of saturated liquid at 0.07 bar and 10 bar are 163.38 kJ/kg and 762.61 kJ/kg respectively. 20

(b) The handle of a saucepan, 30 cm long and 2 cm in diameter is partially immersed in boiling water at 100°C. The average unit conductance over the handle surface is 7.35 W/m^{2}K in the kitchen air at 24°C. The cook is likely to grasp the last 10 cm of the handle and hence, the temperature of this portion should not exceed 32°C. What should be the material conductivity of handle? The handle may be treated as a fin of insulated tip. 10

(c) An artificial spherical satellite flies around the earth. Calculate the temperature of the satellite surface, assuming that there are no heat sources and surface temperature is uniform all over the surface. The solar radiation reflected from the earth and radiation emitted from the earth should also be ignored,

(i) If α_S = 0.2 and ε = 0.1

(ii) If surface of the satellite is gray

(iii) Find the ratio α_S /ε, when the temperature of the satellite surface becomes 30°C. The incident solar radiation is 1500 W/m^2. 10