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 150 words):

(a) Name the common ceramics which are used as tool materials. Describe their method of manufacture in brief. 10

(b) State the condition to avoid the interference when a pinion drives a gear. Calculate minimum number of teeth on the pinion when it meshes with rack having pressure angle 20° and 14.5° respectively. Take standard addendums as one. 10

(c) With usual notations show that the velocity of slider of slider-crank mechanism is expressed approximately by

$$V_p = \omega^2 r\left(\sin\theta + \frac{\sin 2\theta}{n}\right)$$

where n = length of the connecting rod/crank radius. 10

(d) What do you understand by composite materials? Name two composite materials with their applications. 10

(e) For what condition of stresses Mohr's circle is having zero radius. 10

2. (a) What maximum power will be transmitted by a belt of 250 mm wide x 10 mm thick if the stress in the belt is not to exceed 3 N and if the ratio of the driving to slack tension is 2.2, density of material being 1100 kg/m^3?
What is the speed in meter per second at which maximum power is transmitted? Find maximum power. 20

(b) (i) Describe types of chains with necessary diagrams, indicating their construction features.

(ii) In case of chain drive, derive the relationship between pitch of the chain as 'P', pitch diameter of the sprocket and number of teeth 'Z' on the sprocket. 10

(c) Classify types of governors. State what are methods used to increase controlling force. Explain stability of Hartnell governor. 10

3. (a) A beam, 15 meter long, rests on supports 12 meter apart with an overhang of 3 meter at the right hand end. The beam weighs 600 Newton per meter run and carries a concentrated load of 15 kN at the middle of its supported length. Calculate the maximum moment and position of the point of contra-fleaxture. 15

(b) (i) Differentiate between a 'column' and a strut,

(ii) Find the crippling load for a hollow C.I. column of 300 mm external diameter, thickness of metal 40 mm and 8 m long, if both ends are fixed. Take f_c = 550 N/mm^2. Use Rankine's formula. Take a = 1/1600. 15

(c) Differentiate between the functions of the flywheel and the governor. 10

4. (a) What is lattice structure of crystalline materials. Describe all the allotropic forms of Iron giving their lattice structures. Which structure of Iron will give a material having good ductility. Explain the structure with the help of a neat sketch. 20

(b) For the reinforced columns and beams of a building what material is chosen as reinforcement. Give its composition, structure and properties. 20

SECTION 'B'

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

(a) Define the following terms in relation to surface finish:
(i) Lay; (ii) Cut off length; (iii) RMS value; (iv) Roughness; (v) C.L.A. 10

(b) Differentiate between:
(i) Jigs and Fixtures
(ii) Angle of Bite and Angle of Nip
(iii) 2-High and 3-High rolling mills
(iv) Line standard and end standard
(v) Tolerance and allowance 10

(c) Define the following terms:
(i) Use value (ii) Esteem value (iii) Cost (iv) Exchange value (v) Function 10

(d) Give standard ILO symbols used in work-study. 10

(e) Sketch and name control elements of N.C. Machine tool for turning. 10

6. (a) Draw schematic diagram of EDM and name the main components. What are the main characteristics of electrolyte? Give the effect of
(i) current intensity.
(ii) wave form and
(iii) relaxation period on the surface integrity of the machined part. 20

(b) With the help of a sketch, explain how is the unilateral manufacturing tolerance provided on the 'GO' - 'NO GO' gauges for inspecting 20±0.1 mm dia. on a (i) shaft, (ii) hole for (i) workshop and, (ii) inspection gauges. How is the wear allowance given on gauges. 20

7. (a) Enumerate the functions of production planning and control. 5

(b) Ten activities constitute an assembly. The duration of activities and its precedence relation with other activities is given below:

Activity	Duration in secs.	Activity which must precede
1	46	--
2	68	1
3	102	1
4	70	2
5	85	2
6	67	3, 4, 5
7	109	6
8	44	6
9	55	7, 8
10	20	9

There are three assemblers working independently on three stations. Assign the activites to stations such that idel time is minimum. What is the rate of production if the line efficiency is 90% and factory works for 300 day/year on a single shift basis. The production time/shift may be taken as 7 hours. 25

(c) A manufacturer has to establish a line for producing a part if he has to stop outsourcing the same. He has to invest Rs. 2,00,000/- in machines. The material and labour costs per part are Rs. 25/- and Rs. 5/- respectively. The current vendor supplies the part at Rs. 40/- per piece. Should he establish the line, if the required volume is 15,000 parts/annum? 10

8. (a) Why is a flow-chart important in computer programming? Given standard symbols used on flow charts. 5

(b) An automobile shop produces three items - Axle, wheel- drum and wheel ring. The items are produced in lots. The demand rate is uniform and can be taken as deterministic. No back orders are allowed. Using following data, determine approximate economic order quantities when the total value of average inventory levels of these items is Rs. 1000.

Item	Axle	Wheel Drum	Wheel Rims
Holding cost (Rs.)	20	20	20
Set-up cost (Rs.)	50	40	60
Unit cost (Rs.) 6	6	7	5
Demand Rate/Year	10,000	12,000	7,500

Lagrangian multiplier X = 30. 20

(c) A factory manufactures washing machines and dryers. The factory has stamping department, electric motor and transmission department and assembly department. The stamping department and electric motor and transmission department produce parts for both the products while assembly lines are separate for the two products. The monthly departments' capacity are:

Stamping Department	:	1500 washing machine or1500 dryers
Motor and Transmission Department	:	2400 washing machine or 8000 dryers
Washing machine Assembly line	:	4500 washing machines
Dryers Assembly line	:	6000 dryers

Profit per piece of washing machine and dryers are Rs. 300 and Rs. 320 respectively. Formulate linear programming model. 15

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) A reversible engine works between three thermal reservoirs A, B and C. The engine absorbs an equal amount of heat from the thermal reservoirs A and B kept at temperatures T_A and T_B respectively, and reject heat to the thermal reservoir C kept at temperature T_C. The efficiency of the above reversible engine is a times the efficiency of the reversible engine, which works between the two reservoirs A and C.

Prove that: 10

$$\frac{T_A}{T_B} = (2\alpha - 1) + 2(1 - \alpha)\frac{T_A}{T_C}$$

(b) (i) Why a high fuel-air ratio is required during the idling mode of working in a carburettor of a S.I. engine? 5

(ii) What is the function of the condenser and the contact breaker in the battery-ignition system of an S.I. engine? 5

(c) (A) Explain in brief: (i) Vapour lock, (ii) Carburettor icing. 6

(B) What is the cause of diesel smoke? What is the mechanism of smoke formation? 4

(d) Discuss the nature of variation of heat losses from the outer surface of an insulated pipe with increase in thickness of insulation to the surrounding.

What do you understand by the term "critical radius"?

Determine the value of critical radius, if outside heat transfer coefficient from the surface to the surrounding is 15 W/m^2-K and thermal conductivity of insulating materials 0.6 W/m-K. 10

(e) What thermodynamic, physical and chemical properties are to be considered for selection of refrigerants for use in vapour compression refrigeration systems? Discuss their effect on performance and design of the refrigeration systems. 10

2. (a) Show that the Kelvin-Planck and Clausius statements of the Second law of thermodynamics are equivalent. Also prove that all engines operating in the Carnot cycle between two given constant temperature reservoirs have the same efficiency. 10

(b) A closed cylinder of 0.25 m diameter is fitted with a light frictionless piston. The piston is retained in position by a catch in the cylinder wall and the volume on one side of the piston contains air at a pressure of 750 kN/m^2. The volume on the other side of the piston is evacuated. A helical spring is mounted co-axially with the cylinder in this evacuated space to give a force of 120 N on the piston in this position. The catch is released and the piston travels along the cylinder until it comes to rest after a stroke of 1.2 m. The piston is then held in its position of maximum travel by a ratchet mechanism. The spring force increases linearly with the piston displacement to a final value of 5 kN. Calculate the work done by the compressed air on the piston. 15

(c) A pressure vessel has a volume of 1 m3 and contains air at 1.4 MPa, 175°C. The air is cooled to 25°C by heat transfer to the surroundings at 25°C. Calculate the availability in the initial and final states and the irreversibility of this process. Take P_0 = 100 kPa. 15

3. (a) 'The factors which tend to inhibit detonation in S.I. engines tend to promote knock in C.I. engines.' - Examine the above statement in the light of the following factors:
(i) Compression ratio,
(ii) Speed of the engine (RPM),
(iii) Inlet temperature and pressure of air and fuel. 15

(b) (i) Prove that for the same compression ratio the Otto is more efficient than Diesel cycle. 5

(ii) The pressure on the compression curve of a diesel engine are, at l/8th stroke 1.4 bar and at 7/8th stroke 14 bar. Estimate the compression ratio. Calculate the air standard efficiency of the engine if the cut-off occurs at l/15th of the stroke. Also find the fuel consumption per kWhr if the indicated thermal efficiency is 0.5 of ideal efficiency, mechanical efficiency is 0.8 and the calorific value of the fuel is 41,900 kJ/kg. Take γ = 141. 10

(c) An automobile has a 3.2 liter, five cylinder, four stroke cycle diesel engine operating at 2400 RPM. Fuel injection occurs from 20° b TDC to 5° a TDC. The engine has a volumetric efficiency of 0.95 and operates with fuel equivalence ratio of 0.80. Light diesel fuel is used.
Calculate: (i) time for one injection, (ii) fuel flow rate through an injector.
Take stoichiometric air-fuel ratio as 14.5. 10

4. (a) Define the term "Fin effectiveness".
Derive the expression for fin effectiveness of a fin having cross-sectional area A, perimeter p, length L, connected at its base to a wall at temperature T_1 and transferring heat to the surroundings at temperature T_f with surface heat transfer coefficient h. Assume cross-sectional dimensions of the fin to be small relative to its length and heat transfer from the tip of the fin to be negligible. 15

(b) Determine the rate of heat transfer from both sides of a vertical plate at temperature 150°C to the surrounding air at temperature 30°C by natural convection. The height of the plate, L is 1.5 m and width, W = 1 m.
Average heat transfer coefficient for the plate is given by correlation $Nu_L = 0.59 (Ra)^{1/4}$. Properties of air at average temperature are as follows:
Density, ρ = 0.946 kg/m^3, kinematic viscosity, ν = 22.10 × 10^{-6} m^2/s, thermal conductivity = 0.0313 W/m-K, specific heat C_P = 1.009 kJ/kg-K. 15

(c) An enclosure 1 × 2 × 4 m consists of three surfaces: flat surface at the bottom 1 × 2 m, A_1 = 2 m^2, flat surface at the top 1 × 2 m, A_2 = 2 m^2 and all vertical surfaces taken together, A_3 = 24 m^2. All surfaces are flat and A_1 is parallel to A_2. Shape factor F_{1-2} = 0. 035.
Determine the values of following shape factors:
(i) F_{1-3}, (ii) F_{3-2} and (iii) F_{3-3}. 10

SECTION—B

5. Answer any FOUR parts 5.

(a) Explain why the modern day practice is to use high pressure boiler in a thermal power plant with a labelled diagram and stating its unique features, describe La Mont boiler. 10

(b) Explain the working of electrostatic precipitator with a neat diagram and list out its outstanding features over other collectors. 10

(c) Discuss the parameters, which govern comfort in comfort air conditioning. What is "effective temperature" as used in comfort air conditioning? Discuss the comfort charts, used in the design of air-conditioning systems. 10

(d) What is depreciation cost? Explain the commonly used methods for finding out the depreciation cost of the power plant.
The cost of generating unit 1,20,000 rupees and its expected life is 15 years. The salvage value of the plant will be 10% of its installed cost. The maintenance and labour cost per year are 5,000 Rupees. Taking interest on sinking fund as 10%, find the annual cost of the plant. 10

(e) Draw a sketch of an axial flow compressor cascade, and clearly show the following angles:
(i) Blade camber angle (ii) Flow incidence (iii) Flow deviation (iv) Stagger angle. 10

6. (a) (i) With the help of a simple sketch describe the operation of a simple ammonia-water refrigeration system. What is the maximum possible COP of the system for generator temperature = 90°C, absorber temperature = 40°C, condenser temperature = 35°C and evaporator temperature = –5°C?

(ii) Discuss the function of analyser (exhausting column) and dephlegmator (rectifying column) used in ammonia water absorption refrigeration system with the help of simple sketches. How do they improve performance of the system? 15

(b) Calculate the following properties of moist air at dry bulb temperature = 30°C, total pressure = 1.01325 bar and relative humidity = 55% -
(i) Humidity ratio; (ii) Degree of saturation; (iii) Dew point temperature (iv) Enthalpy of moist air and (v) Specific volume
Assume moist air to be a perfect gas mixture. Molecular weight of air Ma = 29, Molecular weight of water, M_w = 18. Universal gas constant = 8.314 kJ/kg mole-K, Specific heat of dry air = 1.005 kJ/kg-K.
Thermodynamic properties of saturated water and steam are as follows:

t_{sat} (°C)	P_{sat} (kPa)	v_g m^3/kg	h_f kJ/kg	h_g kJ/kg
0.01	0.611	206.2	0	2501.6
20	2.34	57.8	83.9	2538.2
25	3.17	43.4	104.8	2547.3
30	4.246	32.9	125.7	2556.4

Assume specific heat of superheated vapour = 1.88 kJ/ kg-K. 15

(c) Define and explain the terms: effectiveness of heat exchanger, ε and number of transfer units, NTU and capacity rate ratio, C. For a counterflow heat exchanger prove that 10

$$\varepsilon = \frac{1 - e^{-(1-C)NTU}}{1 - Ce^{-(1-C)NTU}}$$

7. (a) State the factors affecting the amount of draught to be produced in a boiler. State the merits and demerits of induced draught compared to forced draught. 10

(b) Following data was obtained during the trial on two boilers under similar conditions except that the draught in the first boiler was produced by an induced draught fan and in the second by a forced draught fan:

Boiler house temperature	18.3 C
Mean temperature of flue gases leaving boiler in both cases	185°C
Mean specific heat of flue gases	1.003 kJ/kg/K
Density of flue gases at mean	0.77 kg/m^3

temperature specified	
Air supplied per kg of fuel	19 kg
Density of air under given conditions	1.2015 kg/m^3
Combustion rate	73.3 kg of fuel per sq. m of grate area per hour
Grate area	1.858 sq. meter
Fan efficiency in both cases	50%
Fan draught required in each case	76.4 mm of water gauge

Allow 20% for leakage in case of induced draught system and 10% in case of the forced draught system. Calculate:

(i) Heat carried away by the flue gases in each case.

(ii) Fan power in each case. 15

(c) Air enters in a conical passage with stagnation pressure and stagnation temperature of 5 bar and 400 K respectively. The exit to inlet area ratio of the passage is 4.46. Considering flow of air as isentropic throughout, determine the change in static pressure, if the flow inlet Mach number is (i) 0.7 and (ii) 1.36. The value of A/A* at M = 0.7 and M = 1.36 is 1.094. For air take γ = 1.4 and R = 287 J/kg/K. Take at A/A* = 4.88, M = 12 and 3.15. Sketch the processes on h-s diagram and comment on the resulted change in pressure. 15

8. (a) A multistage gas turbine is to be designed with impulse stages and is to operate with an inlet pressure and temperature of 6 bar and 900 K, respectively. The outlet pressure is 1 bar. The isentropic efficiency of the turbine is likely to be 85%. All stages are to have a nozzle outlet angle of 15°, equal inlet and outlet blade angles, a mean blade speed of 250 m/s and equal inlet and outlet gas velocities considering maximum utilization factor condition, estimate the number of stages required. Take C_P = 1.153 kJ/kg K and γ = 1.333. 20

(b) A centrifugal fan has to deliver 5 m^3/s when running at 750 rpm. The diameter at inlet and outlet of the impeller are 53 cm and 76 cm respectively. The vanes are set backwards at outlet at 70° to the tangent, and the width at outlet is 10 cm. The volute casing gives a 30% recovery of the outlet velocity head. The losses in the impeller may be taken as equivalent to 25% of the outlet velocity head. Assuming that air enters radially with a speed of 15 m/s and neglecting blade thickness effects, determine the manometric efficiency. 20