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.

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SECTION 'A'

1.(a) What is contact ratio for a pair of gears. What is its importance? Determine contact ratio for a pair of two (20°) involute gears of 8 mm module having 23 and 57 teeth. If the addenda on the gears are equal to module, find the contact ratio. 8

1.(b) What is critical speed of a shaft ? Determine critical speed of a shaft 24 mm dia carrying a mass 12 kg at its mid span measuring 1 m. The eccentricity of the mass is 0.11 mm. The material of the shaft is steel with E = 200 GN/m^2. Find the critical speed of the shaft. 8

1.(c) A circular steel rod tapers uniformly from 40 mm diameter to 150 mm diameter in a length of 400 mm. How much the bar will elongate under an axial pull of 40 kN? Take E = 200 GPa. 8

1.(d) A square bar 20 mm x 20 mm in section, 1.5 m long, is freely supported at its ends in a horizontal position and is loaded with a central load of 200 N. The central deflection due to concentrated load is found to be 5 mm.

If the same bar is placed vertically (both ends hinged) and loaded centrally along its axis, what load is likely to cause the bar to buckle? 8

1.(e) What are dual-phase steels? Why are dual-phase steels named so? Enlist important characteristics of dual-phase steels. 8

2.(a) Two pulleys of diameters 480 mm and 640 mm are connected by an open belt drive with distance between two pulleys set at 3 m. It was decided to change the direction of driven pulley (640 mm dia). How much extra length of the belt is required? 10

2.(b) What is partial balancing of reciprocating masses? What are its implications? Determine the unbalanced force when the crank has turned by 45° from t.d.c, after the balancing is done by a mass at 320 mm radius. Only 60% of the reciprocating parts and all the revolving masses are balanced. Determine also the magnitude of balance mass. Single cylinder reciprocating engine data is as below:

Mass of reciprocating parts = 40 kg

Mass of revolving parts = 30 kg at crank radius

Speed of the crankshaft = 150 rpm

Stroke of the engine = 350 mm 10

2.(c) The torque delivered by a two-stroke engine is represented by

$$T = (1000 + 300\sin 2\theta - 500\cos 2\theta)\ \text{N-m}$$

where θ is the angle turned by the crank from inner dead centre. The engine speed is 250 rpm. Mass of the flywheel is 400 kg and radius of gyration 400 mm. Determine

(i) power developed
(ii) total percentage fluctuation of speed
(iii) maximum and minimum torques
(iv) plot torque vs θ for significant points 20

3.(a) A cantilever of length L carries a uniformly distributed load ω/unit length over the entire length. The free end is supported from bottom by a rigid prop. Determine the reaction of the prop. 10

3.(b) A close coiled helical spring made of 8 mm diameter wire has 16 coils. Each coil is 80 mm mean diameter. If the maximum allowable stress in the spring is 150 MPa, determine (i) the maximum allowable load on the spring, (ii) the elongation of the spring and (iii) stiffness of the spring. Take G = Shearing modulus = 82 GPa. 10

3.(c) A thin cylindrical shell with hemispherical ends as thickness of cylindrical portion and thickness of hemispherical portion t_2 The internal pressure for both is same. For no distortion of the junction under pressure what will be the value of ratio of thickness (t_2/t_1) if the material has a Poisson's ratio ν = 0.3. 10

3.(d) A state of stress at a point are given by

$$\sigma_x = 100\ \text{MPa},\ \sigma_y = 80\ \text{MPa and}\ \tau_{xy} = \pm 50\ \text{MPa}.$$

Determine the principal stresses and the maximum shearing stress.
Take: E = 200 GPa, σ_y = 200 MPa and Poisson's ratio ν = 0.3.
Determine the factor of safety according to

(i) maximum principal stress theory
(ii) maximum strain theory and
(iii) maximum shearing stress theory 10

4.(a) Silver is face-centred cubic with lattice constant 4086 A°. Calculate the planar density of atoms (a) on the (100) plane, (b) on the (111) plane and (c) the linear density of atoms along the [110] direction.- 10

4.(b) Calculate percentage of vacant atomic sites in Cu (density = 8900 kg/m^3) at 20°C. Assume that vacancies in Cu at 400°C are 1.62 x 1022/m^3 and constants have following values:

ΔE for vacancy formation = 0.90 eV per vacancy
Boltzman constant, K = 8.62 x 10^{-5} eV/K
Avogadro's number = 6.02 x 10^{23}
Atomic mass of Cu = 63.54 g/mol. 10

4.(c) A tensile test specimen having a diameter of 12.7 mm was loaded up to a load of 76 kN and its diameter was measured as 12 mm. Compare true stress and strain with engineering stress and strain. 10

4.(d) What are the characteristics required for good bearing material? Compare the properties of bearing bronzes, babbits materials and copper-lead alloys for bearings. 10

SECTION 'B'

5.(a) What is the function of MCU in NC machine? A dc servomotor is coupled directly to a lead screw which drives the table of an NC machine tool. A digital encoder which emits 500 pulses per revolution is mounted on the other end of the lead screw. If the lead screw pitch is 5 mm and the motor rotates at 650 rpm, calculate

(i) The linear velocity of the table

(ii) The BLU of the NC system

(iii) The frequency of the pulses transmitted by the encoder 8

5.(b) Define a comparator. Write at least six desirable features it should possess. Also name four types of comparators. 8

5.(c) Write Taylor's tool-life equation. Draw tool-life curves for a variety of cutting tool materials like ceramic, high speed steel, cast alloy and carbide. Why the knowledge of the thrust force in cutting is important? 8

5.(d) What is bill of material (BOM)? Describe single level and multilevel bill of materials. 8

5.(e) The following information is available for a factory:

Daily working hours	8
Number of working days in week	6
Number of operators	20
Standard hours per unit production	4
During a particular week	
Number of units produced	48
Absentee man-days	40
Idle time due to load shedding	30 man-days

Find:

(i) Absenteeism percentage

(ii) Labour utilisation percentage

(iii) Productive efficiency of labour

(iv) Overall productivity of labour in terms of units produced/week/employee. 8

6.(a) Write the design criteria of a jig. Draw a box-jig with open sides arranged for drilling two sides of a block. Name four types of clamping devices. 10

6.(b) Draw a figure to show the wire drawing process and name the process variables. What is recrystallization temperature? Explain impact extrusion. 10

6.(c) Discuss with a figure ultrasonic machining and its applications. Write some characteristics of chemical machining. 10

6.(d) In economics of machining discuss with the help of figures the variation of machining cost and tool cost with cutting speed. The length of a machining element is 500 mm and the part diameter is 100 mm OD. Velocity and feed for this material are 6.9 m/min and 0.5 mm/rev. What is the time to machine? 10

7.(a) Using LPP Graphical method, find the maximum value of

$$Z = 5x_1 + 3x_2$$

subject to constraints:

$$3x_1 + 5x_2 \leq 0$$

$$5x_1 + 2x_2 \leq 0$$

and $x_1, x_2 \geq 0$

Find the values of x_1 and x_2 for the condition for maximization. 10

7.(b) In queueing theory define the following terms:

(i) Queue time
(ii) Move time
(iii) Wait time
(iv) Queue length 10

7.(c) Draw the network diagram for the given data. Find critical path and the project time duration.

Activity	Time	Activity	Time
1-2	2	4-8	8
1-4	2	5-6	4
1-7	1	6-9	9
2-3	4	7-8	3
3-5	1	8-9	5
4-6	5		

10

7.(d) What are the advantages of exponential smoothing method of forecasting? The demand for a wooden article in terms of units for last 8 prior months is given in the table. Compute exponentially smoothed forecast for the periods using $\alpha = 0.1$ and 0.3.

Month	1	2	3	4	5	6	7	8
Demand (units)	10	18	29	15	30	12	16	8

10

8.(a) Discuss with a figure Plasma Arc cutting. Write some advantages of plasma arc torch. Also show with figure cost advantages of plasma over oxyfuel. 10

8.(b) What is QKD? Describe the following two methods of implementing QFD:
(i) House of Quality
(ii) Quality Circles 10

8.(c) A company has demand of 12,000 units/year for an item and it can produce 2,000 such items per month. The cost of one setup is Rs. 400 and the holding cost/unit/month is Rs. 0.15. Find the optimum lot size and the total cost per year, assuming the cost of one unit as Rs. 4. Also find the maximum inventory manufacturing time and total time. 10

8.(d) Write a C-program to store the information of AC units in an electronic retail shop. Use bit fields to store the status information. Assume the AC object consists of the following:
(i) Company name : Samsung, LG, Voltas, Blue Star
(ii) Capacity : One ton, one and half ton
(iii) Power consumption : 2 star, 3 star, 5 star
Assume appropriate number of bits for each field. 10

MECHANICAL ENGINEERING Paper II

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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

Q.1(a) Mention what are the requirements of Ignition System for I.C. Engine. 5

Q.1(b) What do you mean by Scavenging ? Discuss Ideal Scavenging and its limitations. 5

Q.1(c) Explain Air Cooling System for I.C. Engine. 5

Q.1(d) Why is excess air always required to be supplied for combustion? What is excess air factor? 5

Q.1(e) Explain what is meant by critical thickness of insulation. 5

Q.1(f) A refrigeration system exhibits a COP one half of the Carnot cycle operating between the same temperature limits. It removes 600 kJ/min from a reservoir at -100°C while upper temperature is maintained at 200°C. How much energy is rejected to the high temperature reservoir? If the refrigerator was reversed to operate as an engine what is the power developed? 5

Q.1(g) Explain Joule Thomson coefficient. What is inversion temperature? Show the inversion curve and explain the features. 5

Q.1(h) Two equal parallel black discs 0.5 m diameter are located at 0.25 m apart and directly opposite to each other. If the temperatures of the discs are 200 °C and 50 °C, calculate the net heat exchange between them per square meter area. Assume the view factor for this configuration between the plates = 0.38. 5

Q.2(a) The roof of a hemispherical furnace ($\varepsilon = 0.8$) of radius 1 m is maintained at 800 K, while the temperature of the flat circular floor ($\varepsilon = 0.5$) is at 600 K. Calculate the heat loss. What will be the heat loss if both the floor and the roof would have been black? 10

Q.2(b) A full load test on a two-stroke engine yielded the following results:

Speed = 440 rpm
Brake load = 490.5 N
IMEP = 3 bar
Fuel Consumption = 5.4 kg/hour
Rise in jacket water temperature = 36 °C
Jacket water flow = 450 kg/hour
Air fuel ratio by mass = 30 : 1
Temperature of exhaust gas = 360 °C
Temperature of the test room = 19 °C
Barometric pressure = 76 cm of Hg
Cylinder diameter = 22 cm
Stroke = 25 cm
Brake diameter = 1.20 m
Calorific value of fuel = 43000 kJ/kg
Proportion of hydrogen by mass in the fuel = 15%
Given,
R_{air} = 0.287 kJ/kgK, C_p of water = 4.18 kJ/kgK
Specific heat of dry exhaust gases = 1 kJ/kgK
Specific heat of dry steam = 2 kJ/kgK
Assume enthalpy of superheated steam to be 3180 kJ/kg, Calculate,

(i) the indicated thermal efficiency
(ii) the specific fuel consumption in kg/kWh
(iii) volumetric efficiency based on atmospheric conditions.
(iv) Draw up a heat balance for the test on the percentage basis indicating the content of each item in the balance. 20

Q.2(c) Calculate the available energy in 40 kg of water at 75°C with respect to the surroundings at 5°C, the pressure being 1 bar. 10

Q.3(a) Helium contained in a cylinder with piston expands according to the law $PV^{1.2} = C$ from 20 m^3, 5 bar, 220 K to a pressure of 2 bar. Calculate the work done and heat transfer during the process. For helium molecular weight = 4.0, C_p = 5.2 kJ/kg K and γ = 1.66. 10

Q.3(b) Air flows at the rate of 0.5 kg/s through an air compressor, entering at 7 m/s velocity, 100 kPa pressure and 0.95 m^3/kg specific volume and leaving at a velocity of 5 m/s, pressure 700 kPa and specific volume 0.19 m^3/kg. The internal energy of the air leaving is 90 kJ/kg less than that at entry. Cooling water in the compressor jackets absorbs 58 kW of heat. Compute the rate of shaft work input to the air and also calculate the ratio of inlet pipe to outlet pipe diameter. 10

Q.3(c) The volumetric analysis of a fuel gas used in a boiler is given as: C_2H_6 = 22.6%, CH_4 = 73.6%, CO_2 = 2.4%, and N_2 = 1.4%. Assuming combustion air to be dry and in 25% excess, find

(i) the molecular weight of the combustion products
(ii) the total gas volume for complete combustion at 260°C, 1.013 bar and
(iii) the dry flue gas analysis based on CO_2, O_2 and N_2. 20

Q.4(a) Explain the characteristic features of a Pressurized Water Reactor (PWR) with the help of a neat sketch. 10

Q.4(b) Explain what do you mean by Rayleigh Flow. What are the assumptions made? Write down the governing equations for Rayleigh Flow With the help of h-s diagram, show the occurrence of Normal Shock in Rayleigh Flow. 10

Q .4(c) Derive an expression for the temperature distribution for the case of a homogeneous cylinder with uniformly distributed heat source of strength q''' W/m^3 and hence show that

$$\frac{T - T_w}{T_c - T_w} = 1 - \left(\frac{r}{R}\right)^2$$

where T_w is the surface temperature and T_c is the centre temperature for a one dimensional steady state conduction. 15

Q.4(d) Compare between water tube boiler and fire tube boiler. 5

SECTION—B

Q.5(a) In vapour compression refrigeration for an ideal refrigerant, it is desirable that the evaporator pressure should be positive and near atmospheric. Explain why. 5

Q.5(b) Show that in an ideal gas turbine cycle, the optimum pressure ratio corresponding to which the network output is maximum is given by,

$$r_{\text{optimum}} = \left(\frac{T_{\max}}{T_{\min}}\right)^{1/2}$$

where T_{max} and T_{min} are the maximum and minimum temperatures in the cycle. 5

Q.5(c) Show in the form of a table, how do the following properties change in a sensible cooling process and, a cooling and dehumidifying process. Show the processes on a skeleton psychrometric chart: Dry bulb temperature, Wet bulb temperature, Dew point temperature, specific humidity and relative humidity. 5

Q.5(d) Show in the form of a table, how the following flow parameters change in the rotor and stator blades of a 50% reaction axial flow compressor stage:

(i) Absolute velocity
(ii) Static temperature
(iii) Static pressure
(iv) Stagnation temperature and
(v) Stagnation pressure.

Draw the corresponding T-s diagram. 5

Q.5(e) What is a Surge tank? Explain its importance in a hydroelectric power plant. 5

Q.5(f) Explain what do you mean by Kinetic Energy Correction factor. While considering flow through a round pipe, does its value remain constant both for Laminar and Turbulent flows? If not, explain why. 5

Q.5(g) Write down the steady flow energy equation and reduce it to apply for the following systems:

(i) Centrifugal water pump
(ii) Steam turbine
(iii) Steam Nozzle. 5

Q.5(h) A stationary mass of gas is compressed without friction from an initial state of 0.3 m^3, 0.105 MPa to a final state of 0.15 m^3 and 0.105 MPa, the pressure remaining constant.

During the process, an amount of 37.6 kJ of heat is rejected by the gas. What is the change in internal energy of the gas during the process? 5

Q.6(a) An ammonia ice plant operates between a condenser temperature of 35°C and an evaporator temperature of (-15°C). It produces 10 tons of ice per day from water at 30°C to ice at (-5°C). The refrigerant is dry and saturated at the end of compression. Determine:

(i) the capacity of the refrigeration plants in 'TR'

(ii) the mass flow rate of the refrigerant in kg/h

(iii) C.O.P.

Properties of Ammonia:

Sat. Temp.	Sat. liquid enthalpy	Sat. vapour enthalpy	Sat. liquid entropy	Sat. vapour entropy
°C	kJ/kg	kJ/kg	kJ/kg-K	kJ/kg-K
(-15)	112.3	1426.0	0.457	5.549
35	347.5	1471.0	1.282	4.930

Take: C_p water = 4.1868 kJ/kg-K; C_p ice = 1.94 kJ/kg-K

Latent heat of fusion of ice = 335 kJ/kg 15

Q.6(b) Explain the functions of a steam superheater and reheater in a steam power plant. With the help of T-s diagram, explain how do they affect the performance of the steam power plant. 10

Q.6(c) Water enters a counterflow double pipe heat exchanger at 15°C flowing at a rate of 1300 kg/hr. It is heated by an oil (C_p = 2.000 kJ/kg-K) flowing at the rate of 550 kg/hr with an inlet temperature of 94°C. For an area of 1 m^2 and an overall heat transfer coefficient of 1075 W/m^2K, determine the total heat transfer and outlet temperatures of water and oil.

Assume for counterflow exchanger: 10

$$\varepsilon = \frac{1 - e^{-NTU\left(1-\frac{C_{\min}}{C_{\max}}\right)}}{1 - \frac{C_{\min}}{C_{\max}} e^{-NTU\left(1-\frac{C_{\min}}{C_{\max}}\right)}}$$

Q.7(a) Using Buckingham's π-Theorem method, derive suitable parameters to present the thrust developed by a propeller. Assume that the thrust P depends on the:

(i) angular velocity = ω

(ii) speed of advance = *v*

(iii) diameter = D

(iv) dynamic viscosity = μ

(v) Mass density = ρ

(vi) Elasticity of the fluid medium which can be denoted by the speed of sound in the medium C. 15

Q.7(b) Explain Reynold's model law and its applications. 5

Q.7(c) A centrifugal compressor running at 16000 rpm takes in air at 17°Cand 1 bar, and compresses it through a pressure ratio of 4 : 1 with an isentropic efficiency of 82 percent. The blades are radially inclined and the slip factor is 0.85. Guide vanes at inlet give the air an angle of pre-whirl of 20° to the axial direction. The mean diameter of the impeller eye is 200 mm and the absolute air velocity at inlet is 120 m/s. Calculate the impeller tip diameter.

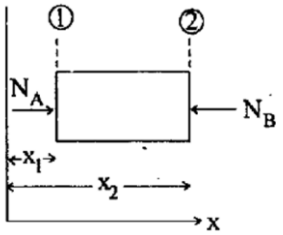
Take C_p = 1.005 kJ/kg-K and γ =1.4

Draw the T-s diagram and the velocity triangles at the impeller inlet and impeller tip. 20

Q.8(a) Show that for equimolal counter diffusion of a two component system as shown in figure, the no. of moles diffused, N_A is given by the following relation:

$$N_A = \frac{D_A(p_{A1} - p_{A2})}{R_0 T(x_2 - x_1)}$$

where D is the diffusion coefficient. 10



Q.8(b) An air-conditioned room is maintained at 25 °C DBT and 50 percent RH, The ambient conditions are 40 °C DBT and 27 °C WBT. The air-handling unit supplies a total of 4500 cmm of dry air which comprises, by weight, 20 percent fresh air and 80 percent recirculated air at the room conditions. The air leaves the cooling coil at 13 °C saturated state. Calculate:

(i) Fresh air load

(ii) Room heat gain

(iii) Total cooling load.

Draw the configuration and show the process on psychrometric diagram. 15

Q.8(c) The original value of an equipment is Rs. 5,00,000/- and its salvage value at the end of its useful life of 20 years is Rs. 50,000/-. Find the value of the equipment at the end of 10 years of its use by the following methods:

(i) Straight line depreciation and

(ii) Sinking fund depreciation

when it is compounded annually at the rate of 8%. 10

Q.8(d) What is the function of the draught system in a steam power plant? Derive an expression to show that for a given chimney height and ambient air temperature, the draught is a function of the flue gas temperature. 5