MECHANICAL ENGINEERING PAPER I

Time allowed: 3 hours **Maximum marks: 300**

INSTRUCTIONS

Each question is printed both in Hindi and in English.
Answers must be written in the, medium specified in the Admission.
Certificate issued to you, which must be stated clearly on the cover of the answer-book in the space provided for the purpose.
No credit will be given for the answers written in a medium other than that specified in the Admission Certificate.
Candidates should attempt Questions **1** *and* **5** *which are compulsory and any* ***THREE*** *of the remaining questions selecting at least* ***ONE*** *question from each Section.*
All questions carry equal marks.
If any data is considered insufficient assume suitable value.
Newton may be converted to kg using the equality 1 kilonewlon (1 kN) = 100 kg, if found necessary.

Section A

1. Answer any three of the following: (Each answer should not exceed 200 words):

20 x 3 = 60

(a) Explain the mechanism of hydrodynamic and boundary lubrications. State with justification the important properties of lubricant in each case.

(b) Explain with the help of velocity and acceleration diagrams why cycloidal profile is preferred over simple harmonic motion profile for cams used in high speed applications.

(c) State and deduce the strain energy of distortion theory of elastic failure and compare it with maximum stress theory with respect to field of application and suitability for optimization.

(d) Write an interactive file-oriented C programme that will maintain the list of names, addresses and telephone numbers in alphabetical order (by last name). Consider the information associated with each name to be a separate record and represent each record as a structure.

2.(a) The controlling force curve of a spring-controlled governor is a straight line. The weight of each governor ball is 40 N and the extreme radii of rotation are 10 cm and 17.5 cm. If the values of the controlling force at the above radii are respectively 205 N and 400 N and the friction of the mechanism is equivalent to 2.5 N at each ball, find:

(i) The extreme equilibrium speeds of the governor; and

(ii) The equilibrium speed and the coefficient of insensitiveness at a radius of 15 cm. 30

(b) What do you understand by direct crank and reverse crank methods in balancing of engines? Explain with illustration, their significance with reference to balancing of radial engines. 30

3.(a) A vertical shaft 20 mm in diameter and 100 cm long is mounted in long bearing and carries a rotor of mass 10 kg midway between the bearings. The centre of the rotor is 0.5 mm away from the axis of the shaft. Neglect the weight of the shaft and take E = 200 GPa for shaft material. Determine the whirling speed of the shaft and the bending stress induced in it when it is rotating at 2000 rpm. 30

(b) A mild steel shaft of 200 mm diameter is to be replaced by a hollow shaft of alloy steel for which the allowable shear stress is 25% greater. If the power to be transmitted is to be increased by 20% and speed of rotation increased by 5%. Determine the maximum internal diameter of the hollow shaft taking its external diameter to be limited to 200 mm. 30

4.(a) The normal stresses at a point in a strained material across two planes at right angles to each other are 120 N/mm^2 tensile and 60 N/ mm^2 compressive. The shear stress on these planes is 40 N/ mm^2. Find:

(i) Principal stresses and principal planes; and

(ii) The direct and shear stresses on a plane inclined at 30° to the vertical. 30

(b) A horizontal beam of square cross-section is so placed that the loading in the transverse plane is along one of its diagonals of length *d*. If the shear force at a section of the beam is *S*, draw the shear stress distribution diagram for the section and indicate the position and magnitude of the maximum shear stress on it. 30

SECTION B

5. Answer any three of the following (each answer should not exceed 200 words): **20 x 3 = 60**

(a) Describe the use of slip gauges for measuring lengths. Outline briefly the principles of working of a mechanical and an optical comparator for comparing lengths stating their relative merits.

(b) What are the characteristics of thermoplastic-plastics and how do they differ from thermo-setting plastics? Name the factors that influence the accuracy of moulding of plastic parts.

(c) What is the importance of materials management in an integrated heavy industry? Explain briefly the function of materials management.

(d) What do you understand by value engineering? Explain the importance of human dynamics in value engineering.

6.(a) Describe with the help of a block diagram the principal components of a typical CNC system. Explain how three different functions like data input, computation and sequence control of a CNC system integrated. 30

(b) What is a tool life? Write Taylor's tool life equation and explain each parameter in it. Plot a typical curve between cutting speed and tool life.

A carbide tool with mild steel work piece was found to give a life of 2 hours while cutting at 0.50 m/min. Compute the tool life if the same tool is used at a speed of 25% higher than the previous one. Also determine the value of the cutting speed if the tool is required to have a tool life of 3 hours. Assume Taylor's exponent n to be 0.27? 30

7.(a) What is the principle behind electrical discharge machining (EDM)? Discuss briefly the process indicating voltage, current and temperature as well as its advantages and limitations. Why is proper flushing so important in this process?

Suggest the required spindle movement for cutting a 5 mm cavity in steel by EDM process using (i) copper electrode and (ii) copper-tungsten electrode. Assume the wear ratio for copper electrode as 2 : 1 and for copper-tungsten electrode as 8 : 1. 30

(b) A motor mechanic has a specialized garage for servicing of Maruti cars. The repair time is exponentially distributed with a mean of 30 minutes. Cars arrive for repair according to Poisson distribution with a mean time of 45 minutes between arrivals. The garage

has a waiting space that can accommodate two cars, excluding the one being repaired. If the waiting area is full, the cars wait outside on the road. What is the expected percentage of cars that have to wait outside because of inadequate waiting space? Instead of cars waiting outside for services, any car that comes for repair goes back not to return again if the waiting area in the garage is full. Find the expected percentage of customers lost due to inadequate waiting space. 30

8.(a) Consider the following schedule of activities and related information for construction of a new International Airport.

Activity	Expected Time		Expected Cost Rupees X 10^4
	Months	Variance	
1 - 2	4	1	5
2-3	2	1	3
3-6	3	1	4
2-4	6	2	9
1-5	2	1	2
5-6	5	1	12
4 - 6	9	5	20
5-7	7	8	7
7 - 8	10	16	14
6-8	1	1	4

Assume that the cost and time required for one activity are not dependent upon the cost and time of any other activity and variations are expected to follow a normal distribution. Find:

(i) the critical path;
(ii) the expected cost of construction of the airport;
(iii) The expected time required to build the airport; and
(iv) The standard deviation of the expected time. 30

(b) The demand for an item in a company is 18,000 units per year. The company can produce these items at the rate of 3000 units per month. The cost of one set-up is Rs 500. The holding cost is Rs 0.15 per unit per month. The shortage cost of one unit is Rs. 20 per year Determine:

(i) Economic production quantity;
(ii) Number of shortages permitted,
(iii) The manufacturing time, and
(iv) Tune between set- ups and maximum inventory level. 30

MECHANICAL ENGINEERING PAPER II

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Section A

1. Answer any three of the following (Answers to each of the parts (a), (b) and (c) should be in about 200 words only): **20 X 3 = 60**

(a) (i) State Clausius inequality theorem and explain its significance An inventor has claimed that he has developed an engine which receives 1000 kJ of heat at a temperature of 1000 K and rejects 200 kJ of heat at a temperature of 600 K, delivering the remaining input as work. Check whether the claim is possible using the above theorem. In case this engine has to be reversible, determine the amount of heat to be rejected. 10

(ii) Determine the pressure of saturated steam at 40ºC if the saturation pressure at 35ºC is 5.628 kPa. The enthalpy of evaporation and the specific volume at 35°C are 2418.6 kJ/kg and 25.22 m^3/kg respectively. Assume that enthalpy of evaporation is essentially constant in this range and R = Pv_g /T. 10

(b) Show using Maxwell's relations: 20

$$C_p - C_v = -T\left(\frac{\partial v}{\partial T}\right)_P^2 \left(\frac{\partial P}{\partial v}\right)_T$$

(c) Explain what do you understand by 'Octane number' of a fuel. Describe how it determined experimentally. 20

(d) Explain the reasons for using supercharging in industrial diesel engines. What are the possible limitations in the application of supercharging in diesel engines? 20

2.(a) (i) Distinguish between available energy and availability. 5

(ii) Oil at 167° C is cooled to 47° C at the rate of 1600 kg/hr in a heat exchanger. Water at 17° C is used at the rate of 6400 kg/hr for the cooling. The specific heat of the oil is 2.1 kJ/kg K Assuming dead state as 17° C, determine the loss in available energy. 15

(b) In the winter season while outside is at 5°C, a heat pump is used to maintain the living space at 20°C. The heat gain into the space is 1.1 kJ/s per degree difference in temperature between inside and outside. Determine the power required to drive the heat pump. If during summer the same motor power is used to maintain the space at 20°C, determine the maximum outside temperature up to which this will be possible. Heat lost rate can be assumed as in the winter season. 20

(c) The efficiency of a reversible engine can be increased in two ways: (i) increasing the source temperature maintaining the sink temperature constant, and (ii) reducing the sink temperature maintaining the source temperature constant.

Show analytically that the second method will lead to larger improvement in efficiency for the same incremental change in temperature. 20

3.(a) Describe the laboratory method of determination of volumetric efficiency of I.C. engines giving the details of calculation. 20

(b) A four cylinder two stroke cycle diesel engine running at 3000 rpm has a bore of 120 mm and stroke of 125 mm. The brake torque was measured as 420 Nm. The volumetric efficiency of the engine is 0.62. The air fuel ratio is 21 : 1. Calorific value of the fuel is 45000 kJ/kg. The density of air at suction was 1.1 kg/m^3. Determine the brake thermal efficiency and brake mean effective pressure. If an orifice tank with orifice diameter of 90 mm was used, determine the water head across the orifice. Take coefficient of discharge for orifice (C_d) =0.60. 40

4.(a) Show that the mass of air, ma, supplied for the combustion of 1 kg of fuel of known carbon content, C%, can be determined from the volumetric analysis of dry products of combustion using

$$m_a = \frac{1}{33}\frac{N_2 C}{CO_2 + CO}$$

where N_2, CO_2 and CO are the percentages by volume of gases nitrogen, carbon dioxide and carbon monoxide respectively. 30

(b) Coal having the following composition is burnt in a furnace:
Carbon 86.1%, Hydrogen 3.9%, Oxygen 1.4% rest ash.
The volumetric analysts of dry products was:
CO_2 = 12.7%, CO = 1.4%, O_2 = 4.1%, N_2 = 81.8%.
Determine the percentage of excess air. Also determine the loss due to incomplete combustion, if CO burning to CO_2 will release 24000 kJ/kg of carbon in CO. 30

SECTION B

5. Answer any three of the following parts (answer to each part should not exceed 200 words):

(a) Derive the integral momentum equation for the boundary layer over a flat plate and determine the boundary layer thickness, δ, at a distance *x* from the leading edge assuming linear velocity profile (u/u_∞) = y/δ where *u* is the velocity at the location at a distance *y* from the plate, and u∞ is the free stream velocity. 20

(b) Describe giving the layout, a refrigeration system that can use solar heat as the input. 20

(c) Derive the following relation using the method of dimensional analysis:

$$\frac{P}{\rho N^3 D^5} = f\left[\frac{Q}{ND^3}.\frac{\rho N D^2}{\mu}\right]$$

where P is the power, *N* is the rpm, *D* is the rotor diameter, *Q* is the volume flow rate and ρ and μ are density and viscosity respectively of the fluid handled. 20

(d) (i) Explain what is meant by stagnation properties of a flowing gas. 5

(ii) Show that stagnation pressure remains constant for reversible adiabatic flow. 5

(iii) Show that for the flow of a gas through a varying cross-section

$$\frac{dA}{A} = -\frac{dV}{V}(1 - M^2)$$

What conclusions can be drawn from the above for area variation for subsonic, sonic and supersonic flows? The symbols have usual meaning. 10

6.(a) Show that the shape factor F_{IR2} for two parallel black surfaces of equal area connected by re-radiating walls at constant temperature is given by

$$F_{IR2} = (1 + F_{1-2})/2$$

where F_{IR2} is the shape factor of surface 1 with respect to surface 2, when connected by re-radiating surface R. 20

(b) A furnace is in the shape of a cylinder of 2 m diameter and 2 m height. The top is at 1000 K while the base is at 700 K. The emissivity of the surface is 0.6. The enclosing curved surface acts as non- absorbing re-radiating surface. Determine the radiation exchange between the top and bottom surfaces. The shape factor between the top and bottom surfaces when sides are open is 0.5. 40

7.(a) Compare vapour compression and vapour absorption systems for the following applications:

(i) Household use
(ii) Ice plant
(iii) Central air-conditioning
(iv) Process cooling, and
(v) Process air-conditioning. 20

(b) A refrigerator with evaporator and condenser temperatures of -10 °C and 32 °C uses R11. The vapour is superheated by 8 °C at entry to the compressor and the superheating is obtained by undercooling the liquid before entry to evaporator. Assuming isentropic compression, determine the power required for a cooling load of 350 kJ/s, the overall efficiency for power use being 75%.

Discuss about the choice of the type of compressor for this plant. Properties values are tabulated below. 40

Temp °C	Specific Volume of vapour m^3/kg	Enthalpy kJ/kg		Entropy of vapour kJ/kg K	Specific heat of kJ/kg K
		liquid	vapour		
-10	0.61141	191.44	384.64	1.7023	0.562
32	0.13104	227.96	406.11	1.6807	0.620

8.(a) A double sided centrifugal compressor has eye root and tip diameters of 18 cm and 30 cm and is to deliver 16 kg of air per second at 16000 rpm. The design ambient conditions are 15° C and 1 bar and the compressor has to be a part of a stationary power plant. Determine

(i) Suitable values for impeller vane angles at the root and tip of the eye if the air is given 20° of pre-whirl at all radii. The axial component of the velocity is constant throughout the impeller and is 150 m/s.
(ii) The power required if the power input factor is 1.05 and mechanical efficiency is 95%, and
(iii) The maximum Mach number at the eye.

Take for air: C_p =1.005 kJ/kg K and C_p / C_v = 1.4. 30

(b) During a boiler trial, steam was produced at a pressure of 20 bar and superheat temperature of 360 °C using feed water at 30 °C at the rate of 90,000 kg/hr. Coal with 3% moisture having calorific value of 34,000 kJ/kg of dry coal was burnt at the rate of 1000 kg/hr. The temperature of flue gases at the exit was 200 °C while inlet air was at 30°C. Coal contains 80% carbon, 6% hydrogen, and rest ash.

CO_2 = 12.7%, O_2 = 10%, N_2 = 78%.

Enthalpy of steam at 20 bar, 360 °C = 3159.3 kJ/kg,
enthalpy of water at 30 °C = 126 kJ/kg, in the flue gas,
the enthalpy of steam at exit condition = 2879.7 kJ/kg,
Specific heat of gas = 1.01 kJ/kg. Draw the heat balance sheet. 30