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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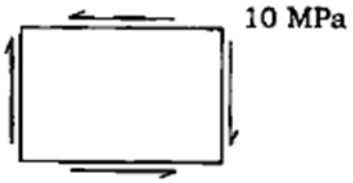
SECTION 'A'

1. (a) In reference to balancing of reciprocating masses, define what is 'Hammer Blow'. If a balancing mass B is kept at a radius b in order to balance the reciprocating parts only, what is the magnitude of the Hammer Blow? What is the effect of Hammer Blow on rail wheels? Give the expression for the permissible angular speed so that the wheels will not lift from the rails. 10

(b) A thick-walled steel cylinder having an inside diameter of 150 mm is to be subjected to an internal pressure of 40 N /mm^2. Find to the nearest mm the outside diameter required, if the hoop stress in the cylinder wall is not to exceed 125N/mm^2. 10

(c) Distinguish between radial follower and offset follower in reference to path of motion of a flat-faced follower-cam mechanism. Draw neat sketches for each of the two. 5

(d) An infinitesimal element of a body subjected to plane stress is found to have the state of stress as shown below:



Draw Mohr's circle for the above state of stress. What is this state of stress called? 5

(e) What is coordination number? Explain with an example. 5

(f) What is 'polymorphism? What changes may take place during polymorphic change? 5

2. (a) (i) Define the phenomenon of interference in mating gears. What is the method of prevention of this?

(ii) A rack and pinion drive has the following data:

Pinion: 20 numbers of involute teeth, 120 mm pitch circle diameter and addendum of 6.25 mm

Rack: Addendum of 6.25 mm

What is the least pressure angle which can be used to avoid interference? With this pressure angle, find the minimum number of teeth in contact at a time. 5 + 15

(b) Show the controlling force vs. radius of rotation graphs for (i) Porter governor and (ii) Spring-controlled governors, and discuss the stability considerations. 10

(c) A machine part of mass 2 kg vibrates in a viscous medium. Determine the damping coefficient when a harmonic exciting force of 20 N results in resonant amplitude of 12 mm with a period of 0.2 second. If the system is excited by a harmonic force of

frequency 4 Hz, what will be the percentage increase in the amplitude of vibration when damper is removed as compared to that with damping? 10

3. (a) A beam of I-section 300 mm depth with flanges 150 mm wide and 20 mm thick, and web 12 mm thick is simply supported over a span of 10 m. If the maximum permissible bending stress is 75 MPa, what concentrated load can be carried at a distance of 3 m from one of the supports? 20

(b) Determine the ratio of the maximum shear stress in the hollow shaft to that in the solid shaft for the following data:
The two shafts are constructed of the same material and have the same length, and same outside radius r. The inside radius of the hollow shaft is 0.6 r. Assume that both shafts are subjected to the same torque. 10

(c) Draw the Bending Moment and Shear Force Diagrams for a simply supported beam of span l and a uniformly distributed load of intensity w/unit length acting over the entire length of the span of the beam. 5

(d) An axial tensile load of 100 kN is applied to a steel rod of 38 mm diameter and 500 mm long. Calculate the change in volume of the rod, if E = 200 GPa and $\nu = 0.26$. 5

4. (a) What is the purpose of 'annealing' and 'tempering' steel? Explain with the help of T-T-T diagram or other diagrams the cycles and the resultant properties in steel. 20

(b) The following data are available in case of a V-belt drive connecting two shafts 1 m apart to transmit' 75 kW at 1200 r.p.m. of driver pulley:
Effective diameter of driver pulley = 300 mm
Effective diameter of driven pulley = 900 mm
Coefficient of friction between belt and pulley = 0.25
Density of belt material = 1100 kg/m^3
Angle of groove = 40° Area of belt section = 400 mm^2
Permissible stress in belt = 2.46 MPa
(i) How many belts are needed?
(ii) Can the driven pulley be flat?
Justify your answer. 10

(c) A simply supported beam of span L and rectangular cross-section (b x h) is loaded by uniformly distributed load of w N/unit length. If σ_{max} is the maximum bending stress and A is the cross-sectional area, then show that the elastic strain energy due to bending of the beam will be given by

$$\left(\frac{\sigma_{\max}^2}{2E}\right)\left(\frac{8}{45} \times \text{Volume of the beam}\right)$$

Sketch the beam. 10

SECTION 'B'

5. (a) How do you define the cutting angles of a single-point tool in (i) International (LMN) and (ii) American (x, y, z) system? Show them in the form of diagrams. 10

(b) Which probability distribution is usually associated with PERT and why? Plot this distribution and indicate on it the relevant parameters of PERT. Which other distribution do you think may be appropriate for the purpose? 10

(c) (i) Why does the tool wear during cutting? Enumerate the possible mechanism of tool wear,
(ii) A tool lasted for 45 min before regrind in a milling operation. The cutting speed was recommended to be increased by 50%, but it was found that now the regrind was needed after every 20 min on an average. Can you define Taylor's tool-life equation valid for this operation, assuming that there is no other change in the system? 5 + 5

(d) Draw a flow chart to find the torque to be transmitted by a solid steel shaft at a specified speed. Maximum shear stress is to be limited to a specified value. Factor of safety, tensile strength of steel and other parameters can be assumed to be given. 10

6. (a) Define 'angle of nip' and/angle of bite' during rolling operation. 20

(b) Calculate the neutral plane to roll 250 mm wide annealed copper strip from 2.5 mm to 2.0 mm thickness with 350 mm diameter steel rolls. Take: $\mu = 0.05$ and $\sigma'_0 = 180$ MPa. 10

(c) (i) What instructions are necessary in typical part programming for NC or CNC machine tool?

(ii) Differentiate between G, M and T functions.

(iii) With an example, explain the difference between word address format and fixed sequential format of instructions. 10

7. (a) A manufacturer of plastic parts uses two machines M-l and M-2 such that each part is processed first on machine M-l and then on M-2. The manufacturer has currently 6 orders / jobs on hand. The estimated processing times and due dates for these jobs are as given in the table below:

Job	Processing time *(in days)*		Due date from now
	M-l	M-2	
A	5	9	37
B	4	6	41
C	7	10	38
D	8	8	47
E	12	9	52
F	9	6	39

(i) Determine the optimum sequence in which jobs can be processed to minimize make span.

(ii) What is the value of make span time?

(iii) What is the average job tardiness resulting from optimum sequence obtained earlier?

(iv) Explain the methodology/algorithm used to get optimum sequence in (i). 10

(b) Majestik Furnitures produces a type of desk that has bill of materials as given in the table below. The desk is made by assembling two drawers, two handles (one for each drawer), one drawer frame, and two legs into a drawer module. Then two drawer modules, a desk-back and a desk-top are assembled into the final product (desk):

Level	Item description	Quantity required	Make/ Buy	Lead time (in weeks)
00	Desk		Make	1
01	Desk-top	1	Buy	2
01	Desk-back	1	Buy	1
01	Leg/drawer module	2	Make	1
02	Drawer frame	1	Buy	1
02	Desk-legs	2	Buy	1
02	Drawers	2	Buy	2
02	Handles	2	Buy	2

(i) Construct the product structure tree for the product (desk).

(ii) Construct a production time chart.

(iii) For the following desk requirements, construct the material requirements plan for the desk and each of its components using lot-for-lot procurement assuming no initial inventories: 20

Week	1	2	3	4	5	6	7	8	9	10
Requirement	—	—	—	—	20	0	50	0	0	30

(c) What is the difference between an -chart and an -R-chart? Why are they used together? 5

(d) Briefly explain the following assumptions of linear programming models: 5

(i) Proportionality

(ii) Certainty

(iii) Additivity

(iv) Divisibility

8. (a) Write a C program to get required inputs from an organization to help them in—

(i) obtaining the break-even quantity for their product(s);

(ii) obtaining profit in rupees from the sale of a specified quantity of product(s), there could also be a loss;

(iii) obtaining total revenue figures at different quantities of sale of their product(s).

State the inputs that you would require.

Draw a flow chart for the above program.

Statements should accompany in your program to explain what is being done. 20

(b) What is the standard of linear measurement? Differentiate between measurement and gauging with reference to the application and method of use. 10

(c) Tourist vehicles arrive at the security check post at the entry of a wildlife park according to Poisson distribution with an average of 10 minutes between two successive vehicles. For security reasons, the time taken to complete the vehicle checking and issuing of vehicle pass is assumed to be exponentially distributed with mean of 9 vehicles per hour. Determine—

(i) the average number of vehicles waiting for the security pass;

(ii) the average time spent by a vehicle in waiting before getting the entry pass;

(iii) the probability that a vehicle arriving at the security check post will have to wait.

State the assumptions made in solving the above problem. 10

MECHANICAL ENGINEERING Paper II

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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/cm² = 0.98 bar

1 bar = 10^5 pascals

Universal gas constant = 8314.6 J/kmol-K

Psychrometric chart is enclosed.

SECTION—A

1. (a) For a gas, the equation of state is expressed as below over a certain range of temperatures and pressures:

$$v = \frac{RT}{P} - \frac{a}{T^3}$$

where a is constant. Prove that the change in enthalpy is given by

$$\frac{4a}{T^3} = (P_1 - P_2)r$$

for isothermal process. Also find out the expression for change of entropy. 8

(b) What is the function of a catalyst in the catalytic converter for smoke emission control? What are the oxidation and reduction processes that take place? Why is unleaded petrol preferred in cars fitted with catalytic converter? 8

(c) What do you mean by compact heat exchanger? What are their applications? 8

(d) Describe the main sources of evaporative emissions in a S.I. engine. 8

(e) A metal plate size 500 mm × 800 mm × 20 mm and thermal conductivity 30 Watt/m-C is maintained at 250°C. Air at 20°C is blowing over the plate. If convection heat transfer coefficient is 25 W/m²C and 200 W is lost by the plate by radiation, compute the inside temperature. 8

2. (a) Consequent upon first law of thermodynamics, show that the heat is a path function. 7

(b) Using pressure – time diagram, explain the combustion process in diesel engine. 8

(c) The following data relates to a two-cylinder four-stroke coal gas engine:

Bore and stroke of cylinder = 380 mm and 585 mm respectively

At 240 rpm, torque developed = 5.16 kNm

Coal gas to air mixture ratio = 1 to 7 by volume

Estimated volumetric efficiency = 85%

Net calorific value of coal gas = 16800 kJ/kg

Calculate the brake power, brake mean effective pressure, piston speed in meter per second and brake thermal efficiency. 20

(d) Draw the labelled schematic diagram of a common rail injection system in a C.I. engine. 5

3. (a) The cylinder volume of an I.C. engine is 3000 cm^3. It contains products of combustion in gaseous form, which can be assumed to be an ideal gas. The combustion products, just before the exhaust valve opens, are at a pressure of 6 bar and temperature of 1123 K. Assuming specific heats at constant volume and constant pressure as 0.718 and 1.005 kJ/kg-K respectively, analyse and discuss the availability of specific energy of the gas. The initial pressure and temperature of gas can be taken as 1 bar and 15°C respectively. 10

(b) What are the characteristics of liquid oil, coal-oil mixture, natural and petroleum gas fuels? What are their major constituents? Where are they suitably used? 15

(c) A sample of coal contains 93% carbon, 6% hydrogen and rest ash. A test was conducted in a Bomb calorimeter using 0.92 kg of coal burnt and following data obtained:

Weight of water taken = 550 gm, Water equivalent of Bomb calorimeter = 2200 gm, Rise in temperature of water = 2.42°C, Fuse wire correction = 10 cal, Acid correction = 50 cal. Taking latent heat of condensation of steam as 530 cal/gm, calculate gross and net calorific value of coal. 15

4. (a) The air-conditioning unit of a pressurised jet aircraft receives its air from the compressor driven by the engine at a pressure of 1.4 bar. The pressure and temperature of the surrounding air at the height of the aircraft are 0.2 bar and 225 K, respectively. The air-conditioning unit consists of a secondary compressor and a turbine mounted on the same shaft. The pressure and temperature of air leaving the turbine are 1 bar and 275 K. Calculate the pressure after the secondary compressor and temperature of air at the exit from the cooler. Assume that all processes are reversible adiabatic. 20

(b) Cold air is to be supplied for a library at a rate of 100 m^3/min. The air is to enter the building at 20°C with 40% relative humidity. Suppose the atmospheric air is available at 35°C with 70% relative humidity suggest a suitable air-conditioning system and estimate the rates of cooling and heating required. 20

SECTION—B

5. (a) Describe in brief how the fly ash is disposed off by 'dry system' and 'wet system'. What problems are caused by present systems of fly ash disposal? Give the applications of fly ash. 8

(b) Name the essential parts of a centrifugal compressor along with their functioning. Sketch a simple figure of a 'diffuser' and write down the names of important parts. 8

(c) With the help of figure, describe the working of 'Velox boiler'. Enumerate its advantages. 8

(d) Derive the expression for temperature distribution for a fin insulated at the end. The base temperature of fin is constant. Write typical application for this type of fin. 8

(e) Describe the desirable properties of refrigerants suitable for ice plant applications. Name a few of these. 8

6. (a) Prove that the simple arithmetic mean temperature difference gives results within 5% compared to LMTD when the ratio of end temperature differences is not more than 2.2. 7

(b) A vapour compression refrigerator uses R-12 as refrigerant and the liquid evaporates in the evaporator at -15°C. The temperature of this refrigerant at the delivery from the compressor is 15°C when the vapour is condensed at 10°C.

Find the coefficient of performance if (i) there is no under cooling (ii) the liquid is cooled 5°C before expansion by throttling. Take specific heat at constant pressure for the superheated vapour as 0.64 kJ/kg-K and that for liquid as 0.94 kJ/kg-K. The properties of refrigerant are as given below: 20

Temp	Enthalpy	Entropy
°C	in kJ/kg	in kJ/kg-K

	Liquid	Vapour	Liquid	Vapour
–15	22.3	180.80	0.0904	0.7051
+10	45.4	191.76	0.1750	0.6921

(c) What are the methods used to reduce the heat radiation between two parallel plates? Write the process, material and specific application of one such technique. 7

(d) Define the second law efficiency of a vapour compression cycle. Derive its efficiency in terms of COP. 6

7. (a) A conical diffuser has entry and exit diameters of 15 cm and 30 cm respectively. The pressure, temperature and velocity of air at entry are 0.69 bar, 340 K and 180 m/s respectively. Determine

(i) the exit pressure ,
(ii) the exit velocity
(iii) the force exerted on the diffuser walls.

For solution the following table may be used. Suffix '0' is corresponding to stagnation pressure values. The star (*) values are critical values corresponding to M = 1. M is Mach number and. M* is corresponding to critical velocity of sound (c*). 15

Isentropic flow of a perfect gas (γ = 1.4)						
M	M*	T/T_0	P/P_0	A/A*	F/F*	$A_P/A^*\ P_0$
0.00	0.00	1.000	1.000	∞	∞	∞
0.05	0.0548	0.999	0.998	11.592	9.158	11.571
0.10	0.1094	0.998	0.993	5.822	4.624	5.781
0.15	0.1640	0.996	0.984	3.910	3.132	3.849
0.20	0.218	0.992	0.973	2.964	2.400	2.882
0.25	0.272	0.987	0.957	2.403	1.973	2.301
0.30	0.326	0.982	0.939	2.035	1.698	1.912
0.35	0.378	0.976	0.918	1.778	1.509	1.634
0.40	0.431	0.969	0.895	1.590	1.375	1.424
0.45	0.483	0.961	0.870	1.448	1.276	1.261
0.50	0.534	0.952	0.843	1.339	1.203	1.129
0.55	0.585	0.943	0.814	1.255	1.147	1.022
0.60	0.635	0.933	0.784	1.188	1.105	0.932
0.65	0.684	0.922	0.753	1.135	1.073	0.855
0.70	0.732	0.910	0.721	1.094	1.049	0.789
0.75	0.779	0.898	0.688	1.062	1.031	0.731
0.80	0.825	0.886	0.656	1.038	1.018	0.681

(b) The maximum demand of a power station is 96,000 MW and daily load curve is described as follows:

Time hours	0-6	6-8	8-12	12-14	14-18	18-22	22-24
Load MW	48	60	72	60	84	96	48

(i) Determine the load factor of power station.
(ii) What is the load factor of standby equipment rated at 30 MW that takes up all load in excess of 72 MW ? Also calculate its use factor. 15

(c) What do you mean by depreciation cost? Name the methods used to calculate the depreciation cost Explain these methods. 10

8. (a) The following data refers to a stage of an impulse reaction turbine:
Steam velocity coming out of nozzle = 245 m/s; nozzle angle = 20°, blade mean speed = 145 m/s; speed of rotor = 3000 rpm; blade height = 10 cm; specific volume of steam at nozzle outlet and blade outlet are 3.45 m /kg and 3.95 m /kg respectively. Power developed by turbine = 390 hp; efficiency of nozzle and blades jointly is 90%; carry over coefficient is 0.82. Determine

(i) the heat drop in each stage
(ii) degree of reaction
(iii) stage efficiency.

Construct velocity triangles. 20

(b) With the help of figure, explain the functioning of 'breeder reactor'. Also enumerate the advantages and disadvantages of breeder reactors. 10

(c) Discuss the site selection for the nuclear power plants based on

(i) population distribution

(ii) land use

(iii) geology

(iv) hydrology. 10