MECHANICAL ENGINEERING Paper I

Time Allowed: Three Hours **Maximum Marks: 250**

Question Paper Specific Instructions

Please read each of the following instructions carefully before attempting questions:

*There are **EIGHT** questions divided in **TWO SECTIONS** and printed both in HINDI and in **ENGLISH**.*

*Candidate has to attempt **FIVE** questions in all.*

*Questions No. **1** and **5** are compulsory and out of the remaining, any **THREE** are to be attempted choosing at least **ONE** from each section.*

The number of marks carried by a question/part is indicated against it.

Answers must be written in the medium authorized in the Admission Certificate which must be stated clearly on the cover of this Question-cum-Answer (QCA) Booklet in the space provided. No marks will be given for answers written in a medium other than the authorized one.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

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SECTION—A

Q1. (a) A cord *ACB*, 5 m long is attached at points A and B to the vertical walls, 3 m apart (Figure 1). A pulley of negligible radius carries a suspended load of 200 N and is free to roll without friction along the cord. Determine the position of equilibrium as defined by the distance *X*, that the pulley will assume and also the tensile farce in the cord. 10

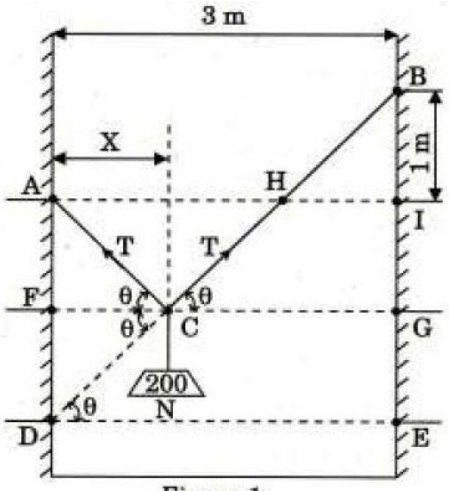


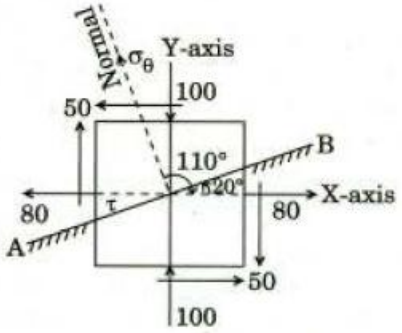
Figure 1

(b) An element with stresses acting on it at a point is shown in Figure 2.

σ_x = 80 MPa

σ_y = –100 MPa

τ_{xy} = ± 50 MPa



All stresses in MPa

Figure 2

Determine: 10

(i) Normal and shear stresses acting on a plane *AB*, whose normal is at an angle of 110° w.r.t. *X*-axis

(ii) Principal stresses and their location

(iii) Maximum shear stress and its location

(c) A shaft is rotating at 150 rpm and it transmits power of 300 kW. The diameter of the shaft is 100 aim, What is the magnitude of torsional shear stress and the twist if the maximum torque is 25% more than the mean torque? The length of the shaft is 1.5 m. Given $G = 85$ GPa. 10

(d) A bar steel shaft of diameter D shows a first critical speed of 1200 rev/min. If the shaft was bored to make it hollow, with an inside diameter of $3/4\ D$, what would be the critical speed? 10

(e) Draw a neatly labelled Imp-iron carbide phase diagram indicating salient regions, phases and reactions. 10

Q2. (a) A block weighing 500 N just starts moving down a rough inclined plane when it is subjected to 200 N force acting up and parallel to the inclined plane and it is moving up the plane when pulled by a force of 300 N parallel to and up the plane. Find the inclination of the plane and the coefficient of friction between the inclined plane and the block. 20

(b) Two involute gears in a mesh have a module of 8 mm and pressure angle of 20°. The larger gear has 57 while the pinion has 23 teeth. If the addenda on pinion and gear wheels are equal to one module, find the following: 20

(i) Contact ratio (The number of pairs of teeth in contact)

(ii) Angle of action of the pinion and the gear wheel

(iii) Ratio of the sliding to rolling velocity at the

I. Beginning of contact

II. Pitch point

III. End of contact

(c) Summarize the microstructures and mechanical properties of the following microconstituents of iron-carbon alloys in terms of phases present, arrangement of phases and relative mechanical properties: 10

(i) Spheroidite

(ii) Fine pearlite

(iii) Bainite

(iv) Tempered martensite

(v) Martensite

Q3. (a) Determine the deflection at points *C* and *D* for the beam loaded as shown in

figure 3. The beam is of rectangular cross-section 150 mm × 300 mm (depth) and E = 200 GPa. 20

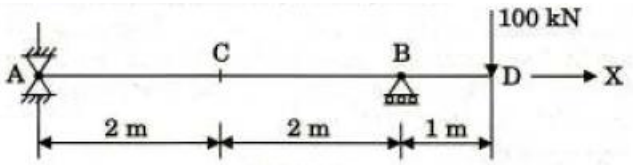


Figure 3

(b) What are cast irons? On the basis of microstructure, briefly explain why gray iron is brittle and weak in tension. Compare gray and malleable cast irons with respect to the following: 10

(i) Composition and heat treatment
(ii) Microstructure
(iii) Mechanical characteristics
(iv) Applications

(c) The arms of a Hartnell governor are of equal length. When the sleeve is in the mid-position, the masses rotate in a circle with a diameter of 150 mm (the arms are vertical in the mid-position). Neglecting friction, the equilibrium speed for this position is 360 rpm, Maximum variation of speed, taking friction into account, is to be 6% of the mid-position speed for a maximum sleeve movement of 30 mm. The sleeve mass is 5 kg and the friction at the sleeve is 35 N.

Assume that the power of the governor is sufficient to overcome the friction by 1% change of speed on each side of the mid-position. While neglecting obliquity effect of arms, find the following: 20

(i) Mass of each rotating ball
(ii) Spring stiffness
(iii) Initial compression of the spring

Q4. (a) A thin cylindrical shell has an external diameter of 500 mm and wall thickness of 10 mm. The length of the cylinder is 1.7 m. Determine the increase in its internal diameter and also the increase in length when the inside pressure is 1 MPa. Given E = 210 GPa and Poisson's ratio = 0.3. Hence determine the change in volume of the cylinder if the ends are closed with flat plates. 20

(b) A pressure tank issues water at A with a horizontal velocity u as shown in Figure 4. For what range of values of un will the water enter the opening BC?

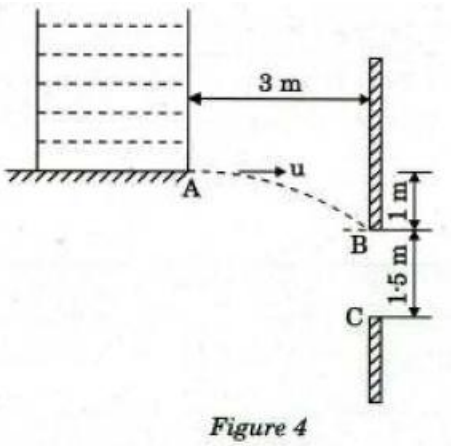


Figure 4

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(c) In a single-degree damped vibrating system, a suspended mass of 8 kg makes 30 oscillations in 18 seconds. The amplitude decreases to 0.25 of the initial

value after 5 oscillations. Determine the following: 20

(i) Stiffness of the spring
(ii) Logarithmic decrement
(iii) Damping factor
(iv) Damping coefficient

SECTION—B

Q5. (a) During an electric discharge drilling of a 10 mm square hole in a low carbon steel plate of 6 mm thickness, brass tool and kerosene are used. The resistance and capacitance in the relaxation circuit are 50 Ω and 10 μF, respectively. The supply voltage is 200 V and the gap is maintained at such a value that the discharge (sparking) takes place at 150 V. Estimate the time required to complete the drilling operation. Approximate relationship between material removal rate (Q) and power (W) for steel material is given by:

$$Q \approx 27.4W^{1.54}$$ 10

(b) A company manufactures a single product having a marginal cost of ₹ 1.50 per unit. Fixed cost is, ₹ 30,000 per annum. The market is such that up to 40,000 units can be sold at a price of ₹ 3.00 per unit, but any additional sale must be made at ₹ 2.00 per unit. Company has a planned profit of ₹ 50,000, Hew many units must be made and sold? 10

(c) Explain the difference between NC and CNC machines mentioning the benefits of CNC machines over NC machines. 20

(d) The demand for a product during the last 10 years is given below. Estimate the demand for the 11^{th} and 12^{th} year by method of regression. 10

Year	1	2	3	4	5	6	7	8	9	10
Unit	124	135	145	150	167	157	161	170	187	168

(e) (i) What is meant by "draft" in relation to rolling process? Determine the maximum possible reduction for cold-rolling a 400 mm thick slab, when μ = 0.07 and the roll diameter is 700 mm. Briefly describe the methods of reducing the roll force by giving suitable explanation. 5

(ii) What is the difference between open-die and impression-die forging? What is barreling in relation to forging? How can it be minimized? How does barreling occur in upsetting of a hot work piece between cold dies and how can it be minimized? Explain the role of flash in impression-die forging. 5

Q6. (a) The table below gives the standard time for the sawing off operation of different jobs being processed at a job order production unit. Table also gives average monthly requirement of each indicated item.

Part Name	Standard time per piece (min)	Average quantity per month
Control shaft	8.46	1,250
Serration shaft	8.46	1,250
Oil pump gear	5.40	4,000
Helical oil pump gear	4.80	2,000
Brake shaft	5.40	1,000
Hub	9.60	2,500

Hex nut	17.16	260
Thread rolls	96.0	30

Assume equipment is running at 75% efficiency with capacity hours at 80% utilisation. Consider 400 hours is available per month per machine. If presently the production unit has 4 power saw machines, determine additional requirement of machines. 20

(b) What do you understand by Just-In-Time (JIT)? What benefits can occur to the company from the application of JIT technique? 15

(c) Melting efficiency in case of an arc welding of steel is given as 30%. The travel speed is 5 mm/sec and the cross-sectional area of the joint is 20 mm^2. Heat required to melt steel may be taken as 10 J/mm^3 and heat transfer efficiency as 85%. Find out the current drawn by the machine, if voltage potential is 20 V. 15

Q7. (a) Mild steel is being machined at a cutting speed of 200 m/min with a tool of rake angle of 10°. The width of cut and uncut thickness are 2 mm and 0.2 mm, respectively. The average value of the coefficient of friction between the tool and the chip is 0.6 and shear stress (τ_s) of the work material is 400 N/mm^2, Using Merchant's first solution, determine: 20

(i) Shear angle

(ii) The cutting and thrust components of the machining force.

(b) Explain the concept of clearance, interference and transition fit. How are fits represented in drawings? 15

(c) A company has got a demand for a particular part at 10,000 units per year. The cost per unit is ₹ 2.00. It costs ₹ 36.00 to place an order and to process the delivery. The inventory carrying cost is estimated at 9% of average inventory investment.

Determine: 15

(i) Economic order quantity

(ii) Optimum number of orders to be placed per annum

(iii) Minimum total cost of inventory per annum

Q8. (a) Quality control department of a tire manufacturing plant has inspected the number of defective tires in twenty random samples with twenty observations each. Following are the number of defective tires found in each sample:

Sample Number	Number of defective tires	Number of observations sampled	Fraction defectives
1	3	20	0.15
2	2	20	0.10
3	1	20	0.05
4	2	20	0.10
5	1	20	0.05
6	3	20	0.15
7	3	20	0.15
8	2	20	0.10
9	1	20	0.05
10	2	20	0.10
11	3	20	0.15

12	2	20	0.10
13	2	20	0.10
14	1	20	0.05
15	1	20	0.05
16	2	20	0.10
17	4	20	0.20
18	3	20	0.15
19	1	20	0.05
20	1	20	0.05

Construct a P-chart 3 standard deviation [three sigma control chart (Z = 3)]. 10

(b) Explain the term Total Quality Management (TQM). 15

(c) What do you mean by extrusion of metals? What are some of the attractive features of this process? What is the primary shape limitation of the extrusion process? Differentiate between direct and indirect extrusion with the help of neatly labelled sketches. What is the primary benefit of indirect extrusion? Briefly describe the three principal extrusion defects. 15

MECHANICAL ENGINEERING Paper II

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QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

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Candidate has to attempt FIVE questions in all.

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SECTION A

1. (*a*) The lighting needs of a classroom are met by 30 Fluorescent lamps, each consuming 80 W of electricity. The lights, in the classroom are kept on for 12 hours a day and 250 days during a year. For a unit electricity coat of ₹ 7 per kWh, determine the annual energy cost of lighting for this classroom. 10

(*b*) A plane wall of thickness 0.2 m and k = 1.2 W/m-K has a surface area of 15 m^2. The left and right sides of the wall are maintained at 120°C and 50°C respectively. Using the basic differential equation for heat conduction, determine the variation of temperature within the wall and the temperature at 0.13 m from the left. Also find the rate of conduction through the wall under steady-state conditions 10

(*c*) A heat pump is to be used to heat a house during the winter as shown in Fig. 1. The house is to be maintained at 21°C at all times. The house is estimated to be losing heat at a rate of 135000 kJ/hr when the outside temperature drops to –5°C. Determine the maximum power required to drive this heat pump:

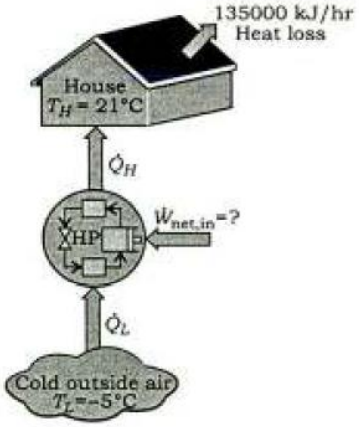

Fig. 1

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(*d*) Differentiate between physical delay and chemical delay with respect to ignition delay period. Also discuss the important engine parameters that affect the ignition delay period. 10

(*e*) Air at 20°C and at atmospheric pressure flows at a velocity of 4.5 m/s past a flat plate with a sharp leading edge. The entire plate surface in maintained at a temperature of 60°C. Assuming that the transition occurs at a critical Reynold's number 5×10^5, find the distance from the leading edge at which the boundary layer changes from laminar to turbulent. At this location, also calculate (i) thicknesses of hydrodynamic and thermal boundary layers and (ii) local and average convective heat transfer coefficients. Assume cubic velocity profile and approximate method. At mean temperature of 40°C, the properties of air are the following:

Density = 1.120 kg/m^3

Kinematic viscosity = 16.96×10^{-6} m^2/s

k =0.02755 W /m-K

Pr = 0.7 10

2. (*a*) A rigid tank contains 10 kg of water at 90 °C. If 8 kg of water is in the liquid form and the rest is in the vapour form, determine (i) the pressure in the tank and (ii) the volume of the tank, Use the relevant data from the saturated water properties (Table 1) provided below for the calculations:

Table 1 : Saturated Water Properties

Temp., T (°C)	Sat. press., P_{sat} (kPa)	Specific Volume (m^3/kg)		Internal Energy (kJ/kg)			Enthalpy (kJ/kg)			Entropy (kJ/kg-K)		
		Sat. liquid, v_f	Sat. vapour, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapour, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapour, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapour, s_g
75	38·597	0·001026	4·1291	313·99	2161·3	2475·3	314·03	2320·6	2634·6	1·0158	6·6655	7·6812
80	47·416	0·001029	3·4053	334·97	2146·6	2481·6	335·02	2308·0	2643·0	1·0756	6·5355	7·6111
85	57·868	0·001032	2·8261	355·96	2131·9	2487·8	356·02	2295·3	2651·4	1·1346	6·4089	7·5435
90	70·183	0·001036	2·3593	376·97	2117·0	2494·0	377·04	2282·5	2659·6	1·1929	6·2853	7·4782
95	84·609	0·001040	1·9808	398·00	2102·0	2500·1	398·09	2269·6	2667·6	1·2504	6·1647	7·4151
100	101·42	0·001043	1·6720	419·06	2087·0	2506·0	419·17	2256·4	2675·6	1·3072	6·0470	7·3542

20

(*b*) What is Reynolds-Colburn analogy? What do you mean by Colburn's *j*-factor? 20

(*c*) What are the different engine cooling systems? Also, mention the important functions performed by the lubrication systems of internal combustion engine. 10

3. (*a*) A heat engine working on ideal Otto cycle has a compression ratio 6. The temperature and pressure at the start of the compression stroke are 27°C and 1 bar respectively. Heat addition in combustion stroke is 1170 kJ/kg. Find out the following parameters :

(i) Maximum temperature of the cycle
(ii) Maximum pressure of the cycle
(iii) Work output per kg of air
(iv) Air standard efficiency of the cycle

Assume the following values for air:
C_v = 0.717 kJ/kg-K and γ =1.4 20

(*b*) A centrifugal compressor under test gave the following data:
Speed = 11500 r.p.m.
Inlet total head temperature = 21°C
Outlet and inlet total head pressure = 4 bar, 1 bar
If the impeller diameter is 75 cm and slip factor is 0.92, what is the compressor efficiency? 20

(*c*) Heat is generated uniformly in uranium (k = 29.5 W/m-K) rods of 5 cm diameter at the rate of 7.5×10^7 W/m^3. Cooling water at 120°C is circulated in the annulus around the rods, with heat transfer coefficient of 55 kW / m^2-K. Find the maximum temperature of the fuel rods. 10

4. (*a*) Water (C_p = 4.187 kJ/kg-K) is heated at the rate of 1.4 kg/s from 40 °C to 70 °C by an oil (C_p = 1.9 kJ/kg-K) entering at 110°C and leaving at 60°C in a counterflow heat exchanger. If the overall heat transfer coefficient is 350 W/m^2-K, calculate the surface area required. Using the same entering fluid temperature and the same oil flow rate, calculate the exit temperature of oil. Also calculate the exit temperatures of oil and water and the rate of heat transfer, when the water flow rate is halved. 20

(*b*) An aircraft is flying at a cruising speed of 250 m/a at an altitude of 5000 m, where the atmospheric pressure is 54.05 kPa and the ambient air temperature is 255.7 K. The ambient air is first decelerated in a diffuser before it enters the compressor (see Fig. 2). Approximating both the diffuser and the compressor to be isentropic, determine the following:

(i) The stagnation pressure at the compressor inlet
(ii) The required compressor work per unit mass, if the stagnation pressure ratio of the compressor is 8.

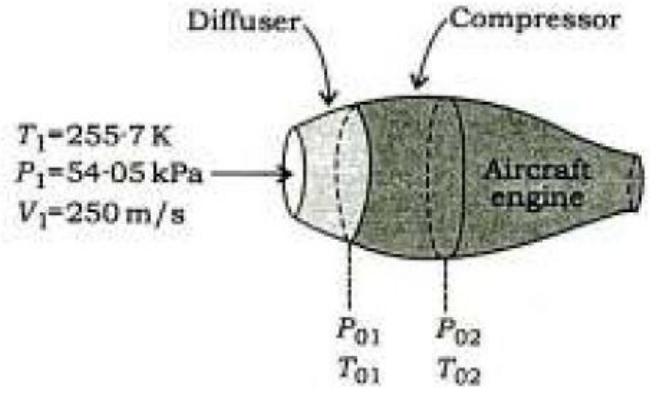

Fig. 2 20

(*c*) Liquid air boiling at −153°C is stored in a spherical condenser of diameter 320

mm. The container is surrounded by a concentric spherical shell of diameter 360 mm in a room at 27°C. The space between the two spheres is evacuated. The surfaces of the spheres arc flushed with aluminium of emissivity 0.03. Taking the latent heat of vaporization of liquid air as 210 kJ/kg, find the rate of evaporation of liquid air. 10

SECTION B

5. (*a*) How are the ratings of the SI and CI engine fuels done? Explain in brief. 10

(*b*) Mention the desirable characteristics of the working fluid in a steam power plant. 10

(*c*) Explain briefly the different types of compressors used in refrigeration. 10

(*d*) Make a typical layout of steam power plant. 10

(*e*) What are human comfort and effective temperature? Sketch comfort zone on psychrometric chart. 10

6. (*a*) The data pertaining to an impulse turbine are as follows:
Blade speed = 300 m/s
Isentropic enthalpy drop in nozzles = 450 kJ/kg
Nozzle efficiency = 0.9
Nozzle angle = 20°
Blade velocity coefficient = 0.85
Blade exit, angle = 25°
Sketch the velocity diagrams and calculate for a mass flow rate of 1 kg/s the following :

(i) The inlet angle of moving blade
(ii) The axial thrust
(iii) The driving force on the wheel
(iv) The diagram power
(v) The energy Lost in the blades due to friction. 20

(*b*) In a laboratory test, a psychrometer recorded dry-bulb temperature as 35°C and wet-bulb temperature as 28°C. Calculate (i) vapour pressure, (ii) relative humidity, (iii) specific humidity, (iv) vapour density in air, (v) dew point temperature and (vi) enthalpy of mixture. Barometric pressure is 1.01325 bar. Do not use psychrometric chart. Saturation pressures of water vapour at 35°C and 28°C are 0.05628 bar and 0.03782 bar respectively. Saturation temperature at partial pressure of water vapour is 25.6°C. 20

(*c*) What is the difference between direct injection and indirect injection type combustion chambers of CI engines? Make labelled diagrams of any two types of combustion chambers used in CI engines. 10

7. (*a*) During an engine trial of a four-stroke diesel engine, the following observations were recorded:
No. of cylinder = 4
Diameter of piston = 10 cm
Stroke length = 15 cm
Indicated mean effective pressure = 0.67 MPa
Speed = 2000 r.p.m,
No. of explosions = 980 per minute
Brake torque = 181.5 N-m

Fuel consumption = 11.89 kg/hr
Calorific value of fuel = 41800 kJ/kg
Relative efficiency (on brake power basis) = 0.5
Quantity of jacket cooling water = 1020 kg/hr
Rise in temperature of cooling water = 35°C
Specific heat of cooling water = 4.18 kJ/kg-K

Based on the above observations, find out the following engine parameters:

(i) Mechanical efficiency
(ii) Brake thermal efficiency
(iii) Air standard efficiency
(iv) Brake specific fuel consumption
(v) Percent heat loss to jacket cooling water. 20

(*b*) (i) Discus the effect of variation of back pressure on mass flow rate and pressure distribution in a convergent-divergent nozzle.
(ii) What do you mean by supersaturated flow of steam in nozzles? 20

(*c*) Draw a neat sketch of summer air-conditioning system and show the process on psychrometric chart. 10

8. (*a*) A Freon-12 refrigerator producing a cooling effect of 20 kJ/s operates on a simple cycle with pressure limits of 1.509 bar and 9.607 bar. The vapour leaves the evaporator dry saturated and there is no undercooling. Determine the power required by the machine. If the compressor operates at 300 r. p.m. and has a clearance volume of 3% of stroke volume, determine the piston displacement of the compressor, For compressor, assume that the expansion is following the law $PV^{1.13}$ = constant. Specific heat of vapour at condenser pressure is 0.747 kJ/kg-K:

Table : *Properties of Refrigerant* R-12

Pressure (bar)	t (°C)	v_g (m³/kg)	Enthalpy (kJ/kg)		Entropy (kJ/kg-K)
			h_f	h_g	s_g
1.509	–20	0.1088	54.23	178.61	0.7082
9.607	40	–	74.53	203.05	0.682

20

(*b*) Explain how the ideal regenerative cycle may approach to Carnot cycle efficiency. Also, mention the reason as why ideal regenerative cycle cannot be achieved in practice. 20

(*c*) Explain the working of practical NH_3-water vapour absorption refrigeration system with a diagram. 10