**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 Nos. 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**

**1.** (a) A beam *AB* of length 2 m, hinged at *A* and supported at *B* by a cord which passes over two frictionless pulleys (*P*, *Q*), carries a 50 kN load as shown in Fig. 1(a). Determine the distance *x*, where 100 kN load is located on the beam, if the beam is to remain in equilibrium in horizontal position. Also determine the reaction at the hinged end.

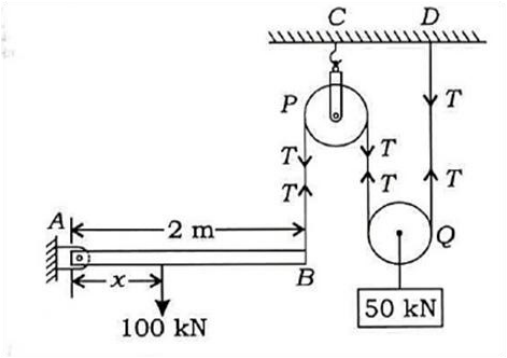



Fig. 1(a). 10

(b) A state of plane stress is shown in Fig. 1(b).

Determine the following:

(i) Principal stresses

(ii) Principal planes

(iii) Maximum shear stress

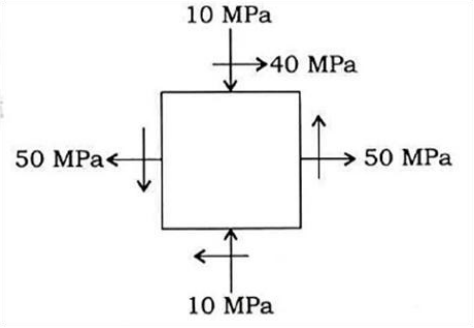



Fig. 1(b) 10

(c) A thin spherical vessel of 1000 mm diameter and 2 mm thickness is subjected to an internal pressure of 4 MPa. The Young's modulus and Poisson's ratio are 200 GPa and 0.3 respectively. Find the following:

(i) Hoop stress

(ii) Change in volume of the vessel 10

(d) A steam engine develops 300 kW power at 9.5 rad/s. The coefficient of fluctuation of energy is found to be 0.1 and fluctuation of speed is kept within ±0.5% of mean speed. Find the mass of the flywheel required if the radius of gyration is 2 m. 10

(e) A machine of mass 8 kg is supported on springs having combined stiffness of 5.4 N/mm. A dashpot is attached to the system that exerts a force of 40 N, when the mass has a velocity of 1 m/s. Determine the following:

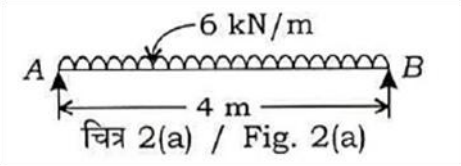
(i) Critical damping coefficient

(ii) Damping factor

(iii) Logarithmic decrement

(iv) Ratio of two consecutive amplitudes 10

**2.** (a) A simply supported beam of rectangular section is 200 mm wide and 300 mm deep. It supports a uniformly distributed load of 6 kN/m over an effective span of 4 m as shown in Fig. 2(a). Calculate the magnitude and direction of the principal stresses at a point located at 0.50 m from the left support and 50 mm above the neutral axis.




चित्र 2(a) / Fig. 2(a)

15

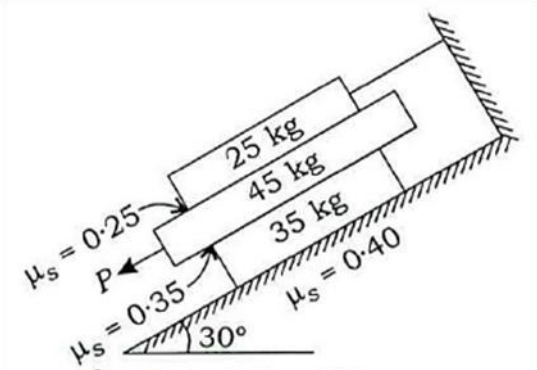
(b) Compare the permissible diameter of a steel circular shaft, subjected to torsion, according to the following theories of failure. Assume Poisson's ratio to be 0.3 :

(i) Maximum stress theory

(ii) Maximum shear stress theory

(iii) Maximum strain theory 15

(c) Fig. 2(c) shows three flat blocks positioned on the 30° incline. A force *P* parallel to the incline is applied to the middle block. The movement of the upper block is prevented by attaching to a fixed support by a wire. The coefficient of static friction for each of the three pairs of mating surfaces is shown in the figure. Determine the maximum value which P may have before any slipping takes place.



चित्र 2(c) / Fig. 2(c)

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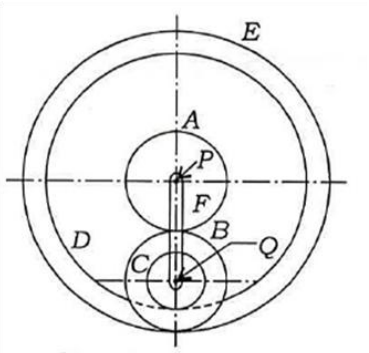
**3.** (a) A solid aluminium shaft 1 m long and 50 mm diameter is to be replaced by a tubular steel shaft of the length and the same outside diameter (i.e., 50 mm) such that each of the two shafts could have the same angle of twist per unit torsional moment over the total length. What must the inner diameter of the tubular steel shaft be? The modulus of rigidity of steel is three times that of aluminium. 20

(b) A compound epicyclic gear is shown in Fig. 3(b). Gears *A*, *D* and *E* are free to rotate on axis *P*. Compound gears *B* and *C* rotate together on axis *Q* at the end of arm *F*. All the gears have equal pitch. The number of external teeth on gears *A, B* and *C* are 18, 45 and 21 respectively. Gears *D* and *E* are annular gears. Gear *A* rotates at 100 r.p.m, in counter-clockwise direction and gear *D* rotates at 450 r.p.m. clockwise. Find the speed and direction of arm *F* and gear *E*.



चित्र 3(b) / Fig. 3(b)

15

(c) For a eutectoid steel, draw and label continuous cooling transformation (CCT) diagram. Explain normalizing and hardening heat treatment with regard to phase transformation using relevant cooling curves on CCT diagram. 15

**4.** (a) Four masses *A, B, C* and *D* are attached to a shaft and revolve in the same plane. The masses are 12 kg, 10 kg, 18 kg and 15 kg respectively and their radii of rotation are 40 mm, 50 mm, 60 mm and 30 mm respectively. The angular positions of masses *B, C* and *D* are 60°, 135° and 270° from the mass *A*. Find the magnitude and position of balancing mass at a radius of 100 mm. 20

(b) Draw the stress-strain diagram for mild steel and describe the salient points of the curve. 10

(c) A Porter governor having all arms of 240 mm length is pivoted on the axis of rotation. Each ball has a mass of 5 kg and the load on the sleeve is 18 kg. The ball path is 150 mm when the sleeve begins to rise and 200 mm at the maximum speed. Find the following :

(i) Range of speed

(ii) Coefficient of sensitiveness, if the friction at the sleeve is equivalent to a force of 10 N 20

**SECTION B**

**5.** (a) Electrochemical machining of 400 $mm^2$ surface of iron is performed using supply voltage of 15 V and tool-workpiece gap of 0.3 mm. Considering gap resistance for the flow of current through electrolyte to be 0.0015 Ω, calculate the metal removal rate, MRR ($m^3/s$).

The relevant data for iron are the following :

Valency = 2

Atomic weight = 55.85

Density = 7860 $kg/m^3$

Faraday's constant = 96540 coulombs 10

(b) An annealed copper plate of 300 mm width and 20 mm thickness is rolled to 16 mm thickness in one pass. Considering radius of the roller as 400 mm, rotational speed of 80 r.p.m. and average flow stress during rolling as 400 MPa, calculate the true strain and rolling force (kN). 10

(c) The machining of steel is carried out using two types of cutting tool, i.e., tool *A* and tool *B*. Data/technical parameters related with tools are given below in the table. Which tool will you prefer for 200 minutes of tool life and why?

| *Tool* | *Value of n for tool life equation* | *Cutting speed for one minute tool life (m/min)* |
|---|---|---|
| Tool *A* | 0.25 | 150 |
| Tool *B* | 0.30 | 180 |

10

(d) Describe the philosophy of lean management including waste and value stream with regard to manufacturing. 10

(e) The demand for an item is 500 units and 600 units for July and August respectively. Considering forecast for July as 300 units, determine the forecast for September using exponential smoothing method. Assume value of $\alpha$ as 0.3. 10

**6.** (a) For orthogonal turning using a cutting tool having a rake angle of 5°, the following data is given :

Chip-thickness ratio = 0.5

Rake angle = 5°

Main cutting force = 1600 N

Thrust force = 1300 N

Calculate the shear plane angle, friction force (N), normal force (N) and coefficient of friction at chip-tool interface. 20

(b) Two aluminium plates are welded using tungsten inert gas (TIG) welding process with the help of welding current 150 A, arc voltage 12 V and arc travel speed 2 mm/s. Considering heat transfer efficiency of TIG welding process as 90% and heat required for melting unit volume of metal (Al) as 15 $J/mm^3$, calculate the melting efficiency of the process if the cross-sectional area of the weld joint is 20 $mm^2$. 15

(c) Explain the principle of abrasive waterjet machining using suitable schematic. Write the advantages and applications of abrasive waterjet machining. 15

**7.** (a) The following limits are specified to give a clearance fit between a shaft and a hole in a limit system :

Shaft = $30^{-0.08}_{-0.021}$ mm $\phi$

Hole = $30^{+0.023}_{-0.000}$ mm $\phi$

Calculate the following :

(i) Basic size

(ii) Shaft and hole tolerances

(iii) Shaft and hole limits

(iv) Maximum and minimum clearances 15

(b) Lathe machine operations take 40 min to produce a product. If the efficiency of the lathe machine is 80% and rejection is 20%, then determine the number of lathe machines required for producing 800 pieces per week. Assume 52 weeks per year and 48 hours per week as working hours available. 20

(c) A manufacturing company is producing an item for which the following information is given :

Selling price per unit = ₹ 20

Variable cost per unit = ₹ 10

Fixed cost = ₹ 2,00,000

However due to changing market condition, variable cost increased by 20% and fixed cost increased by 10%. If the breakeven quantity is maintained, then what will be the revised selling price? 15

**8.** (a) Monthly consumption of an item is 350 units and price per unit is ₹ 15. Inventory carrying cost is 20 percent and ordering cost is ₹ 40 per order; lead time of 1 month's stock. Assuming ROL system, calculate the following :

(i) Reorder quantity

(ii) Reordering level

(iii) Minimum level

(iv) Maximum level

(v) Average inventory 15

(b) A car manufacturer performs final inspection before shipping to the dealers. The final inspection involves testing and inspection of car with regard to number of parameters. There is a possibility that a car may fail to satisfy various parameters (which can be termed as defects). Periodically ten (10) cars were taken randomly for testing and inspection. Data obtained after inspection and testing of each car with regard to number of defects is given below. Determine the control limits for C chart and comment :

| *Sample/Car* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *No. of defects* | 10 | 12 | 13 | 08 | 09 | 10 | 12 | 20 | 07 | 06 |

15

(c) Describe different types of control systems possible for CNC operations along with respective applications using suitable schematic. 20

**MECHANICAL ENGINEERING Paper—II**

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**QUESTION PAPER SPECIFIC INSTRUCTIONS**

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**SECTION—A**

**1.** (a) An insulated rigid tank is divided into two equal parts by a partition. Initially, one part contains 4 kg of an ideal gas at 800 kPa and 50°C, while the other part is evacuated. The partition is now removed and the gas expands into the entire tank. Determine the final temperature and pressure in the tank. 10

(b) Show processes of saturated vapour compression refrigeration cycle on *p-v, t-s* and *p-h* diagram and mark graphically on *t-s* diagram refrigerating effect, heat rejection by condenser and compressor work. 10

(c) What is the shape factor in case of radiative heat exchange? Discuss the four (4) basic shape factor laws. 10

(d) Draw valve timing diagrams of 4-stroke high speed and low speed SI internal combustion engine. 10

(e) Define steam, quality and derive expression for specific volume of steam in terms of steam quality. $v = v_f + xv_{fg}$ 10

**2.** (a) The efficiencies of the compressor and turbine of a gas turbine are 70% and 71%, respectively. The heat added in the combustion chamber per kg of air is 476.35 kJ/kg. Find a suitable pressure ratio such that the work ratio is 0.054. Also find the corresponding temperature ratio. The inlet total temperature of air is 300 K. 20

(b) A flue gas stream is to be monitored for its temperature using a thermocouple. The thermocouple design needs to be evaluated in terms of its time response to accurately predict the measured temperature. The thermocouple junction can be approximated as a sphere of diameter 0.6 mm, density of the bead material ($\rho$) 8500 kg/m$^3$, thermal conductivity ($k$) is 30 W/m-K; specific heat (c) is 0.3

kJ/kg-K. The convective heat transfer coefficient (h) between the junction and flue gas is 300 W/m$^2$-K. Determine the time required to read 90% of the initial temperature difference. Neglect radiation effect and change in thermophysical properties with temperature. 20

(c) Classify different types of boilers and discuss factors important for the boiler selection. 10

**3.** (a) In an open heart surgery, under hypothermic conditions, the patient's blood is cooled before surgery and rewarmed afterwards. It is proposed that a concentric tube counterflow heat exchanger of length 0.5 m is to be used for this purpose, with a thin walled inner tube having diameter of 55 mm. If water at 60°C and 0.1 kg/s is used to heat the blood entering the heat exchanger at 18°C at a flow rate of 0.01 kg/s, what is the temperature of the blood leaving the heat exchanger?

One may assume, overall heat transfer coefficient (U) = 500 W/m$^2$-K, specific heat of blood and water are respectively $C_{P_{blood}} = 3.5$ kJ/kg-K, $C_{P_{water}} = 4.187$ kJ/kg-K. 20

(b) A single cylinder 4 stroke SI engine is producing 100 KW power at an overall efficiency of 20%. Engine uses a fuel-air ratio of 0.07 : 1. Determine how many m3/hr of air is used if air density is 1.2 kg/m$^3$. The fuel vapour density is 4 times that of air. How many m$^3$/hr of mixture is required? Calorific value of fuel is 42000 kJ/kg. 20

(c) The pressure in an automobile tyre depends on the temperature of the air in the tyre. When the air temperature is 25°C, the pressure gauge reads 210 kPa. If the volume of the tyre is 0.025 m$^3$, determine the pressure rise in the tyre when the air temperature in the tyre rises to 50°C. Also, determine the amount of air that must be bled off to restore pressure to its original value at this temperature. Assume the atmospheric pressure is 100 kPa and gas constant of air, R = 0.287 kPa m$^3$/kg-K. 10

**4.** (a) A six cylinder 4-stroke diesel engine has a bore of 60 mm and a crank radius of 32 mm. The compression ratio is 9 : 1 and engine volumetric efficiency is 90%. Determine :

(i) Stroke length
(ii) Mean piston speed at 1000 rpm
(iii) Swept volume per cylinder
(iv) Clearance volume per cylinder
(v) Cubic capacity of the engine
(vi) Actual volume of air aspirated per stroke in each cylinder 20

(b) The rotor of an axial flow fan has a mean diameter of 30 cm. It runs at 1470 rpm. Its velocity triangles at entry and exit are described by the following data: Peripheral velocity components of the absolute velocities at entry and exit are:

$$C_{y_1} = \frac{1}{3}u \; C_{y_2} = \frac{2}{3}u$$

where $C$ = fluid velocity, $u$ = peripheral speed

(i) Draw the inlet and exit velocity triangles for the rotor and prove that the work is given by $W_c = \frac{1}{3}u^2$

(ii) Calculate the pressure rise, take a constant density of air, $\rho$ = 1.25

kg/m$^3$. 20

(c) Explain clearly what is "thermally developed zone" in case laminar flow through a tube both for (i) constant wall temperature case (ii) constant heat flux case. 10

**SECTION—B**

**5.** (a) What is the difference between 'normal' and 'oblique' shock? State the significance of each. 10

(b) Explain harmful effects of R-12 and R-22 refrigerant. Write their chemical formula and NBP temperature. Also suggest new ecofriendly substitutes of these two with chemical composition. 10

(c) Discuss experimental determination of calorific value of solid fuel with a neat diagram. 10

(d) The air-fuel ratio of an SI engine varies from no-load to full load condition. Write air-fuel ratio requirement for an engine under following conditions with reason :

(i) Idling condition
(ii) Cruising condition
(iii) High load condition
(iv) Cold-start condition 10

(e) A sample of fuel was found to have the following percentage analysis by weight: C 80; $H_2$ 16; and ash etc. 4. Determine the minimum weight and volume of air required to bum 1 kg of this fuel. Density of $O_2$ is 1.429 kg/m$^3$. 10

Properties of Refrigerant R-134a

| Pressure (bar) | $t$°C | $V_g$, (m$^3$/kg) | Enthalpy (kJ/kg) | | Entropy (kJ/kg-K) | |
|---|---|---|---|---|---|---|
| | | | $h_f$ | $h_g$ | $S_f$ | $S_g$ |
| 2.104 | –10 | 0.0994 | 186.7 | 392.4 | 0.9512 | 1.733 |
| 8.870 | 35 | — | 249.1 | 417.6 | 1.1680 | 1.715 |

**6.** (a) A single stage, single acting vapour compression refrigeration system uses R-134a. Condenser and evaporator temperatures are 35°C and –10°C and refrigerant is undercooled by 5°C. Clearance volume per swept volume is 0.03 and swept volume is 269.4 cm$^3$. Compressor speed and efficiency are 2800 rpm and 80% respectively. Expansion index is 1.12. Determine (i) Compressor exit temperature (ii) Enthalpy of refrigerant at compressor exit (iii) Enthalpy at the exit of the subcooler (iv) Volumetric efficiency of compressor (v) Refrigerant mass flow rate. Specific heat of vapour and liquid at condenser pressure are 1.1 kJ/kg-K and 1.458 kJ/kg-K respectively. Assume suction vapour dry saturated and isentropic compression. 20

(b) (i) Explain about (I) back pressure turbine (II) by-product power cycle (III) co-generation plant (IV) tri-generation plant. 10

(ii) Define overall efficiency, boiler efficiency, cycle efficiency, mechanical efficiency and generator efficiency of a Rankine cycle based power plant and also prove that :

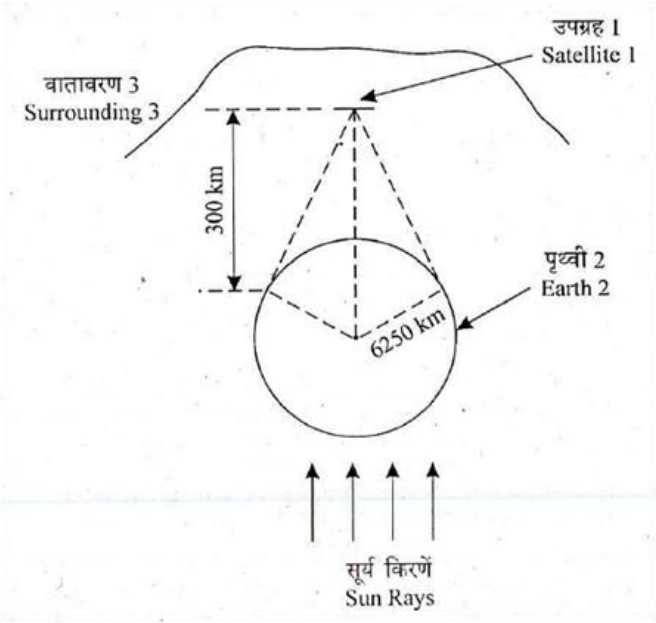
$$\eta_{overall} = \eta_{boiler} \times \eta_{cycle} \times \eta_{mechanical} \times \eta_{generator}$$ 10

(c) A supersonic wind tunnel settling chamber expands air through a nozzle from a pressure of 10 bar to 4 bar in the test section. Calculate the stagnation temperature to be maintained in the settling chamber to obtain a velocity of 500 m/s in the test section. Take $C_{Pair}$ = 1.025 kJ/kg-K and $C_{Vair}$ = 0.735 kJ/kg-

K. 10

**7.** (a) The mean diameter of the blades of an impulse turbine with a single row wheel is 105 cm and the speed is 3000 rpm. The nozzle angle is 18°, the ratio of blade speed to steam speed is 0.42 and the ratio of the relative velocity at outlet from the blades to that at inlet is 0.84. The outlet angle of the blade is to be made 3° less than the inlet angle. The steam flow is 8 kg per sec. Draw the velocity diagram for the blades and estimate the (i) resultant thrust on the blades (ii) tangential thrust on the blades (iii) axial-thrust on the blades (iv) power developed in blades and (v) blade efficiency. 20

(b)




A small disc-shaped earth satellite, 1 m in diameter circles the earth (radius 6250 km) at a distance of 300 km from the surface. The flat surface of the disc is oriented tangential to the earth's surface. The satellite surface has an emissivity of 0.3 and is at −18°C. Calculate the net rate at which energy is leaving the satellite.

Assume that:

(i) The average earth surface temperature is 27°C and the earth is black body.

(ii) The satellite is in shadow of the earth and

(iii) The part of the satellite surrounding not occupied by the earth is black and at 0 K.

(iv) Stefan-Boltzmann constant ($\sigma$) = $5.67 \times 10^{-}8$ W/m$^2$-K$^4$. 20

(c) Differentiate clearly between ventilation and infiltration. Discuss the methods of estimation of infiltrated air. 10

**8.** (a) The engine test on a single cylinder four stroke diesel engine has following observations :

Test duration = 1 hr
Bore × Stroke = 0.3 m × 0.45 m
Fuel consumption = 11.4 kg
Calorific value of fuel = 42 MJ/kg
Indicated mean effective pressure = 6 bar
Net load on brake = 1500 N
Engine rpm = 300 rpm

Brake drum diameter = 1.8 m
Brake rope diameter = 20 mm
Quantity of the jacket cooling water = 600 kg
Temperature rise of cooling water = 55°C
Quantity of exhaust measured = 290 kg
Exhaust gas temperature = 420°C
Specific heat of exhaust gas = 1.03 kJ/kg-K
Ambient temperature = 20°C

Estimate:

(i) The indicated power
(ii) The brake power
(iii) The indicated thermal efficiency
(iv) Draw up an energy balance sheet 20

(b) In an air-conditioning plant, an air handling unit supplies a total of 4000 $m^3$/min of dry air which comprises by mass 20% of fresh air at 39°C DBT and 26°C WBT and 80% re-circulated air at 24°C DBT and 50% RH. The air leaves the cooling coil at 12°C saturated. Using Psychrometric chart calculate (i) Total cooling load and (ii) Room heat gain. Also show the process on Psychrometric chart. 20

(c) Write down the assumptions to analyze a counterflow heat exchanger using LMTD (Log mean temperature difference) method and also write down the expression for LMTD in a counterflow heat exchanger with the help of terminal temperatures. 10