Civil Services (Main) Examination, 2014

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.

Candidate has to attempt FIVE questions in all.

Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.

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

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

Word limit in questions, wherever specified, should be adhered to.

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.

SECTION 'A'

1. **(a)** A particle of mass m is resting at point B on a smooth semicircular cylinder of radius r, tied to a point A vertically above the centre of the cylinder at a height of 2 r, with a string of length 1.1 r as shown in Fig. 1(a). If the string is cut, find the angle θ defining the position C of the particle where it jumps off the cylinder. **10**

[Figure: Fig. 1(a) – Smooth semicircular cylinder of radius r resting on a horizontal (hatched) ground, centre O on the ground line. Point A lies vertically above O at height 2 r; the vertical line OA is marked r (from O up to the top of the cylinder) and r (from the top of the cylinder up to A). A string of length 1.1 r runs from A to the particle at point B on the cylinder surface; OB makes angle α with the vertical. Point C on the surface further along the same side; OC makes angle θ with the vertical.]

(b) Stresses at a point are shown in Fig. 1(b). What is the shear stress on plane AC, if τ on plane BC is 40 MPa? What is the magnitude of angle θ if AB is a principal plane? What is the maximum shear stress at the point? **10**

[Figure: Fig. 1(b) – Right-angled triangular element ABC with the right angle at C: BC horizontal (bottom), AC vertical (right side), AB the inclined hypotenuse making angle θ with BC at B. A normal compressive stress of 60 MPa acts on face AC (arrow pointing into the face from the right); a normal stress of 100 MPa acts on face BC (arrow pointing downward, away from the face) together with a shear stress τ along BC (arrow pointing towards C).]

(c) Describe different crystal systems in Materials. **10**

(d) A pinion having 30 teeth drives a gear having 80 teeth. The profile of the gears is involute with 20° pressure angle, 12 mm module and 10 mm addendum. Find the length of path of contact, arc of contact and contact ratio. **10**

(e) The vibrations of a machine of mass 76 kg are damped by a viscous dashpot which diminishes amplitude of vibrations from 17.2 mm to 3.2 mm in two complete oscillations. The machine is mounted on four springs each of stiffness 7.5 N/mm. Assuming that the damping force varies as the velocity, determine: (i) the damping coefficient, (ii) the ratio of frequencies of damped and undamped vibrations, and (iii) the periodic time of damped vibrations. **10**

2. **(a)** Derive expressions for longitudinal and hoop stresses in a thin walled pressure vessel. Using the above expressions, determine hoop and longitudinal stresses in a household LPG cylinder, assuming it to be a thin walled pressure vessel with following dimensions: OD – 315 mm thickness: 2.8 mm. Take end caps to be flat and the pressure in the cylinder is 1.4 MPa at room temperature. **20**

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(b) Describe Austempering of steel with help of TTT diagram. **10**

(c) A cam drives a flat reciprocating follower in the following manner: During first 120° rotation of the cam, the follower moves outwards through a distance of 20 mm with simple harmonic motion. The follower dwells during next 30° of cam rotation. During next 120° of cam rotation, the follower moves inwards with simple harmonic motion. The follower dwells for the next 90° of cam rotation. The minimum radius of the cam is 25 mm. Draw the profile of the cam. **20**

3. **(a)** A shaft is to transmit 2 kW at 750 R.P.M. The shaft is supported in bearings A and C, 300 mm apart. Two pulleys of 300 mm diameter and 150 mm diameter are located at B and D as shown in Fig. 3(a). Assume that the belt tensions are vertical for both pulleys. Ratio of belt tensions for both pulleys is 3. Neglect weight of pulleys and shaft. Take combined fatigue and shock factor in bending and twisting equal to $K_b = 1.5,\ K_t = 1.0$, respectively. Determine uniform diameter of the shaft if allowable tensile stress is 110 MPa and allowable shear stress is 65 MPa. (Take shaft diameter in steps of 5 mm.) **20**

[Figure: Fig. 3(a) – Horizontal shaft supported in bearings A (left) and C; pulley B (300 mm ϕ) between A and C, pulley D (150 mm ϕ) overhanging beyond C at the right end. Distances along the shaft: A to B = 120 mm, B to C = 180 mm, C to D = 60 mm.]

(b) What are polymeric materials? Distinguish between two polymer types. **10**

(c) Because of nature of its operations, the load torque of a machine is intermittent as follows: During its three quarter revolution, the load torque increases uniformly from 10 kNm to 15 kNm. Thereafter it remains constant for half revolution and then decreases uniformly in three quarter revolution to 50 kNm. After this for one revolution it remains constant. Thus the cycle is repeated. The machine is run by a constant torque motor running at a speed of 300 rpm, in conjunction with a flywheel of mass moment of inertia of $2200\,kg/m^2$. Determine: (i) Magnitude of mean torque of motor (ii) Power of the motor (iii) Speed fluctuation of the system. **20**

4. **(a)** A solid circular shaft is subjected to a bending moment of 3 kN-m and a torque of 1 kN-m. The shaft is to be made in carbon steel for which $\sigma_y = 480\,MPa$ and $\tau_y = 265\,MPa$. Calculate shaft diameter using: (i) Maximum normal principal stress theory (ii) Maximum shear stress theory. **20**

(b) What are composites? How are they classified? Mention any four applications of composites. **10**

(c) An epicyclic speed reduction gear schematic is shown in Fig. 4(c). Compound wheel B–C is free to rotate on pin A connected to driving shaft. Wheel 'C' meshes with fixed wheel 'E' and wheel 'B' meshes with wheel 'D' keyed to driven shaft. If number of teeth on wheels are $T_b = 27$, $T_c = 30$, $T_d = 24$ and $T_e = 21$, determine the ratio of speeds of the driving and driven shafts. **20**

[Figure: Fig. 4(c) – Schematic: the driving shaft (left) is cranked to form arm A, which carries a pin on which the compound wheel B–C rotates freely (B the larger wheel, C the smaller, both above the axis). B meshes with wheel D keyed to the driven shaft (on the common axis); C meshes with wheel E, which is fixed to the frame (hatched). The driven shaft emerges to the right through the fixed frame.]

SECTION 'B'

5. **(a)** Compare flank wear and crater wear and draw tool life versus cutting speed curves for H.S.S., Carbide, and ceramic tools. **10**

(b) Define 'Grinding Ratio'. Also explain what is meant by a grinding wheel acting soft or acting hard. Is it always desirable to obtain a high grinding ratio in practice? **10**

(c) A company studied the cost data on quality and found a relationship between the percent defective and the cost of control and cost of failure per 100 parts as under: Cost of failure $F = 1500 + 120\,X$ Cost of Control $C = \dfrac{3000}{X}$ where X is percent defective. What is the percent

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defective which minimizes the quality cost? How much is the minimum quality cost per hundred parts? **10**

(d) Fixed and variable costs for three potential manufacturing facilities for same product are shown below: **10**

Mfg. Facility	Fixed Cost/Yr. (Rs.)	Variable Cost/Unit (Rs.)
A	1,25,000	50
B	2,00,000	40
C	2,50,000	20

(i) If the expected output is to be 8000 units per year, which facility should be selected? Explain with the help of a graph. (ii) When is option B economical? (iii) Comment on choice of the options.

(e) Differentiate between open loop, closed loop and adaptive control systems used in NC machine tools. **10**

6. (a) According to the ISO system, sketch the basic size, deviation, and tolerance on a shaft and hole assembly. Why uni-lateral tolerance is preferred over bi-lateral tolerance? **10**

(b) Explain with the help of a sketch the Electric Discharge Machining (EDM) process. What are its advantages and limitations? Describe the nature of the surface obtained by EDM. Also name any three important electrode materials. **20**

(c) Explain with neat sketches the Plasma Arc Welding (PAW) process and discuss its applications and limitations. **20**

7. (a) List five distinct methods used to obtain high energy rates in HERF. With the help of a sketch explain the spark discharge method of High Energy Rate Forming. Also mention two advantages and three important applications of HERF method. **20**

(b) State the basic principles of plant layout. Table below lists 12 work-elements along with their immediate predecessor elements and duration in minutes. Design suitable line consisting of appropriate work-stations assuming a cycle time of 20 minutes. Compute the line efficiency, balance delay and smoothness index: **20**

Work Element	Immediate Predecessor Element	Duration
A	–	10
B	A	6
C	B	8
D	A	6
E	B	12
F	E	10
G	F	4
H	G	12
I	F	2
J	F	8
K	G	8
L	H, I, K	14

Use the least-number-of predecessors rule.

(c) A transport company assumes that the requirement of tyres used in vehicles are closely related to number of kilometres driven. Accordingly, the following data covering the last six months have been collected as follows: **10**

Months	Tyres Used	Thousands of km driven
1	100	1500
2	150	2000
3	120	1700
4	80	1100
5	90	1200

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6	180	2700

(i) Establish the relationship (linear) between the required tyres and kms driven based on data. How good is the co-relation? (ii) If expected kms drive in a month is 32,00,000, forecast the demand for tyres.

8. **(a)** Compare the concept of 'Just-in-Time' with that of 'Manufacturing Resource Planning'. A work centre uses Kanban containers which hold 200 parts. To produce enough parts to fill the container 60 minutes are needed. Moving the container to the next work-station and return of empty container takes 120 minutes. There is overall demand rate of 6 units per minute. (i) Calculate the number of containers needed for the system. (ii) What is maximum inventory in the system? (iii) If the setup and runtime to fill the container is reduced to 40 minutes, can the number of containers be reduced? How much will be the inventory in system then? **20**

(b) What is understood by "process is under statistical control"? Explain clearly with the help of diagrams, illustrating out of control situations. Plot the control charts of $\overline{X}$ and R, using the following sample data and a sample size of 5. From the chart, find out whether the process is under control. **20**

Subgroup No.	1	2	3	4	5	6	7	8	9	10
$\overline{X}$	5.004	5.204	5.014	5.008	5.009	5.016	5.030	5.010	5.016	5.010
R	0.02	0.08	0.03	0.05	0.04	0.09	0.04	0.04	0.05	0.07

The factors for estimating σ' from R and σ from statistical tables are reproduced below:

Number of observations n	2	3	4	5	6	7	8	9	10	11
$d_2 = \overline{R}/\sigma'$	1.128	1.693	2.059	2.326	2.534	2.704	2.847	2.970	3.078	3.173
$c_2 = \overline{\sigma}/\sigma'$	0.5642	0.7236	0.7979	0.8407	0.8686	0.8882	0.9027	0.9139	0.9227	0.9300

(c) A manufacturing organisation is considering investment in two alternative equipments A and B. Equipment A costs Rs. 30,000 while the equipment B costs Rs. 50,000. The expected yearly net income for the first five years from these equipments are Rs. 10,000 and Rs. 15,000 for equipments A and B respectively. Assuming the cost of capital as 12% per annum, determine which equipment should be selected. Use net present value approach. **10**

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