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.

Unless otherwise mentioned, symbols and notations have their usual standard meanings. Assume suitable data, if necessary and indicate the same clearly. Neat sketches may be drawn, wherever required.

SECTION A

Q1.(a) Draw the displacement-cam angle and velocity-cam angle diagrams of constant acceleration and deceleration of cam-follower profile. What are its limitations? 8

(b) Explain the terms: cycle, amplitude, phase angle and natural frequency related to mechanical vibrations. 8

(c) Describe the Mohr's circle diagram as applied to two-dimensional stress, indicating principal dimensions and angles and what they represent. 8

(d) What is meant by dislocation?
State different types of dislocations with neat sketches. 8

(e) Show that the forging load can be estimated using the expression, $P = 1.15\bar{\sigma}\ A$, where $\bar{\sigma}$ = mean yield stress, A = cross-section area. 8

Q2.(a) A hoisting drum, carrying a steel wire rope, is mounted at the end of a cantilever beam as shown in Fig. 1. Determine the equivalent spring constant of the system when suspended length of the wire is l. Assume that the net cross-sectional diameter of the wire is d and the Young's modulus of the beam and wire rope is E. 10

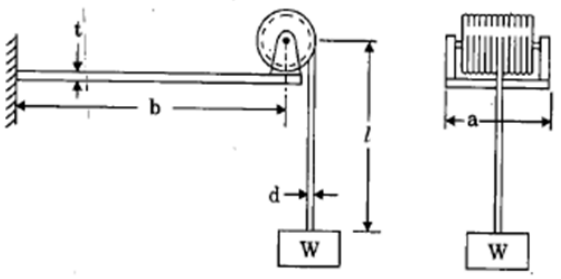

Fig. 1

(b) A simply supported circular beam of diameter D is subjected to a load of W. It is desired to replace this beam by a hollow beam having 80% flexural strength, but with outside diameter D_1 and inside diameter 0.5 D_1. Compare the weight of both beams for flexural strength, if they are supported over same span. 10

(c) The total sleeve movement in a spring controlled Hartnell governor is 30 mm. The mass of rotating balls is 1.4 kg each. At the mid-position of the sleeve, the sleeve arm, which is 65 mm long, is horizontal. The ball arm is 75 mm long. The balls rotate at a radius of 100 mm when the sleeve is at mid-position. Due to the wrong adjustment of spring, the top speed of the governor is 422 rpm and that corresponding to the lower position is 435 rpm. Determine

(i) the stiffness of the spring, and

(ii) the required initial compression of the spring to give an equilibrium speed at the topmost position which is 12 rpm more than at the lowest position, if the sleeve mass is neglected. Neglect the effect of obliquity of arms. 20

Q3.(a) A flat belt drives a pulley having angle of lap of 115° and coefficient of friction of 0.3 between belt and pulley. The belt is made of neoprene rubber of density 900 kg/m^3 and is 86 mm wide and 6 mm thick. The maximum stress which the belt can sustain without deformation is 2 MPa. If the belt is used to drive a 100% efficient generator, what will be the power output of the generator and at what speed of the belt? 10

(b) It is proposed to balance 50% of the reciprocating masses in a single cylinder reciprocating engine, which is rotating at 150 rpm. The masses of revolving and reciprocating parts are 30 kg acting at crank radius and 40 kg respectively. If the stroke is 350 mm, find

(i) the balance mass required at a radius of 320 mm, and

(ii) the unbalanced force at the crank position of 45° from the dead centre.

Take acceleration due to gravity, g = 9.80 m/s^2. 10

(c) A shaft S_1 has two interconnected gears A and B mounted on it. The gear A is in mesh with gear C mounted on shaft S_2. Gear D is mounted on shaft S_3, which is co-axial to shaft S_2. Gears B and D are in mesh. The module of connected gears A and C is 2 mm and that of B and D is 3 mm. The speed of the shaft S_3 is approximately less than 1/12 (one-twelfth) of that of shaft S_2. The number of teeth on pinions B and C are 24 each. Find the

(i) suitable number of teeth on gears, pinions,

(ii) actual velocity ratio, and

(iii) distance between shafts S_1 and S_2. 20

Q4.(a) Write briefly on grey cast iron and white cast iron. 10

(b) What is annealing? Explain the following terms:

(i) Full annealing

(ii) Process annealing

(iii) Stress-Relief annealing 10

(c) Explain the following structures:

(i) BCC

(ii) FCC

With the help of examples, bring out the essential differences in properties and applications of two materials which have BCC and FCC structures. What is the name assigned to the materials which change their structure from BCC to FCC? 20

SECTION B

Q5.(a) (i) What are the important constituents of linear programming?

(ii) State the assumptions to be made in formulation of a problem in linear programming. 8

(b) (i) Differentiate value-analysis and value engineering.

(ii) State different phases of value-analysis job-plan and explain any one of them. 8

(c) What are the effects of lowering the friction at the tool-chip interface (with lubricant) on the mechanics of cutting operations? 8

(d) In an orthogonal cutting operation, the following data have been observed:

Uncut chip thickness = 0.128 mm
Width of the cut = 6.36 mm
Cutting speed = 2.0 m/s
Rake angle = 10°
Cutting force = 568 N
Thrust force = 228 N
Chip thickness = 0.228 mm
Find shear angle, friction angle and cutting power. 8

(e) Using Taylor equation for tool life, and assuming n = 0.5 and C = 400, calculate the percentage increase in tool life when the cutting speed is reduced by 50%. 8

Q6.(a) Name and discuss the factors that contribute to the formation of

(i) discontinuous chip
(ii) chips with built-up edge 10

(b) (i) Draw the velocity diagram in cutting zone and prove that

$$\frac{V_S}{V} = \frac{\cos\alpha}{\cos(\varphi - \alpha)}$$

where, V : Cutting velocity
V_s : shear velocity
α : rake angle
φ : shear angle

(ii) Why is it not always advisable to increase the cutting speed in order to increase the production rate? 10

(c) With the help of *sketches,* explain the following terms related to rolling of sheet metal:
(i) Angle of bite
(ii) Neutral plane
(iii) Draught
(iv) Camber **20**

Q7. (a) For a particular product, the following information is given:
Selling price per unit: Rs 100
Variable cost per unit: Rs 60
Fixed costs: Rs 10,00,000
Due to inflation, the variable costs have increased by 10% while fixed costs have increased by 5%. If the break-even quantity is to remain constant, by what percentage should the sales price be increased? **10**

(b) A manufacturing company purchases 9,000 parts of a machine for its annual requirement, ordering one month's requirement at a time. Each part costs Rs 20. The ordering costs are Rs 15 per order and the carrying costs are 15% of the 'average inventory per year. Suggest a more economic purchasing policy for the company. What will be your advice and how much would it save the company per year? **10**

(c) Arrivals at a telephone booth are considered to be Poisson distributed with an average time of 8 minutes between one arrival and the next. The length of phone call is assumed to be distributed exponentially with mean 3 minutes.
(i) What is the probability that a person arriving at the booth will have to wait?
(ii) What is the average length of the queue that forms from time to time?
(iii) What is the probability that it will take him more than 12 minutes altogether to wait for the phone and complete his call? **20**

Q8. (a) Explain laser beam machining process with the help of a figure. Mention hole depth-to-diameter ratio, energy density and application. **10**

(b) (i) Explain the springback effect in sheet metal forming.
(ii) What are the advantages and limitations of high energy rate forming (HERF) process? **10**

(c) Explain Merchant's force diagram for orthogonal cutting.
A steel work piece is machined with orthogonal cutting using a tool of 10 degree rake angle. The chip thickness ratio is 0.31. The vertical and horizontal cutting forces are 1200 N and 650 N respectively. Using Merchant's theory,
(i) Calculate the work done in cutting of metal to overcome friction and shear stress.
(ii) Give assumptions made, if the depth of cut is 2 mm and feed is 0.20 mm/revolution, the cutting speed is 200 m/minute.
(iii) Calculate the total work done. **20**

MECHANICAL ENGINEERING PAPER—II

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 Nos. 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 chronological 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.

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

Assume suitable data, if necessary and indicate the same clearly.

Neat sketches may be drawn, wherever required.

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/cm^2 = 0.98 bar 1 bar = 10^5 pascals

Universal gas constant = 8314.6 J/kmol-K

SECTION—A

1. Answer all of the following:

(a) A balloon is filled with hydrogen. It has 1000 m^3 volume at temperature 300 K and pressure 100 kPa. Determine the payload that can be lifted with the balloon. 8

(b) A two-stroke CI engine delivers a brake power of 368 kW, while 73.6 kW is used to overcome friction losses. It consumes 180 kg/hr of fuel at an air-fuel ratio of 20:1. The heating value of the fuel is 42000 kJ/kg. Calculate *(i)* indicated power, *(ii)* mechanical efficiency, *(iii)* air consumption, *(iv)* indicated thermal efficiency and *(v)* brake thermal efficiency. 8

(c) Explain with T-s arid *P-h* diagrams the effect of superheating and subcooling in vapour compression cycle of refrigeration. 8

(d) Prove the Clapeyron equation

$$\left(\frac{dP}{dT}\right)_{Saturation} = \frac{h_{fg}}{Tv_{fg}}$$

where the terms have their usual meanings. 8

(e) What do you mean by effectiveness of heat exchangers? Derive the expression for effectiveness of parallel-flow heat exchanger. 8

2. (a) A circumferentially finned tube with inner diameter 3 cm, outer diameter 32 cm, having thermal conductivity 15 W/m-K is provided with 2 fins/cm. The outer diameter of circumferential fin is 4.5 cm and its thickness is 1 mm and is made of the same, material as the tube.

The finned tube is used to cool water, which flows inside the tube, by transferring heat to air which flows across the finned tube. Heat transfer coefficients on air and water side are 15W/m^2-K and 500 W/m^2-K respectively. Effectiveness of fins is 0.65.

Calculate the value of overall heat transfer coefficient for the finned tube based on inside surface area of the tube. 15

(b) Three thinned-wall infinitely long hollow cylinders 1, 2 and 3, having radii 7.5 cm, 12.5 cm and 17.5 cm respectively, are arranged concentrically. The surface of the cylinder 1 is maintained at 727 °C, while the surface of cylinder 3 is maintained at 27 °C. Emissivities of all surfaces of the cylinders are 0.08.

Calculate the steady-state temperature of cylinder 2, if there is high vacuum in the annular spaces between the cylinders. 15

(c) What is Fick's law? On what factors does the rate of mass transfer depend in molecular diffusion? 10

3. (a) Discuss in brief various factors which affect the volumetric efficiency of an engine. 10

(b) A six-cylinder petrol engine develops 62 hp at 3000 RPM. The volumetric efficiency at NTP is 85%. The bore is equal to the stroke and thermal efficiency of 25% may be assumed. Calorific value of petrol is 10500 kcal/kg. Air-fuel ratio is to be 15:1. Calculate cylinder bore and stroke. 15

(c) A four-cylinder four-stroke petrol engine was subjected to a laboratory test and the following data were obtained:

Cylinder diameter = 64 mm
Stroke length - 90 mm
Fuel consumption = 7.5 liters/hr
RPM = 2400
Calorific value of fuel = 11400 kcal/kg
Specific gravity of fuel = 0.717
Brake drum diameter = 73.5 cm
Rope diameter = 2.5 cm
Load on brake drum running at one-third engine speed by belts, spring balances read 60 kg and 8 kg. Mechanical efficiency = 80%
Determine *(i)* brake thermal efficiency and *(ii)* indicated mean effective pressure. 15

4. (a) Which is the more effective way to increase the efficiency of a Carnot engine–to decrease T_1 keeping T_2 constant or to decrease T_2 keeping T_1 constant? 10

(b) The Joule-Kelvin coefficient μ_j is a measure of the temperature change during a throttling process. A similar measure of the temperature change produced by an isentropic change of pressure is provided by the coefficient μ_s, where 15

$$\mu_s = \left(\frac{\partial T}{\partial P}\right)_S . \text{prove that } \mu_s - \mu_j = V/C_p$$

(c) In a steam power station, steam flows steadily through a 0.2 m diameter pipeline from the boiler to the turbine. At the boiler end, the steam conditions are found to be p = 4MPa, t = 400°C, h =3213.6 kJ/kg and v = 0.073 m^3/kg. At the turbine end, the conditions are found to be p = 3.5MPa, t = 392 °C, h = 3202.6 kJ/kg and v = 0.084 m^3/kg. There is a heat loss of 8.5 kJ/kg from the pipeline. Calculate the steam flow rate. 15

SECTION—B

5. Answer all of the following:

(a) What is the function of a thermostatic expansion valve used in vapour compression refrigeration systems? Discuss with the help of neat sketch the working of an internally equalized thermostatic expansion valve. How does it differ from an externally equalized thermostatic expansion valve? 8

(b) Air enters an insulated pipe at Mach number (M) =0.4 and leaves at M = 0.6. What portion of the duct length in percentage is required for the flow to occur at $M = 0.5$? 8

Take Fanno line parameters as

M	fL/D
0.4	0.5770
0.5	0.2673
0.6	0.1227

(c) The moist air at 25 °C, total pressure of 100 kPa and 50% RH is compressed to 50 °C, total pressure of 300 kPa and then cooled at constant pressure. At what temperature will water begin to condense? Show the process on psychometric

chart. 8

(d) Why is there a need of governing of steam turbines? With the help of a simple sketch, discuss the working principle of hydromechanical speed-governing loop for steam turbine. 8

(e) With the help of a sketch, discuss the working principle of temperature control in steam boiler. 8

6. (a) A simple R-12 plant is to develop 5 tonnes of refrigeration. The condenser and evaporator temperatures are to be 40 °C and -10 °C respectively. Determine the following:

(i) Refrigerant flow rate
(ii) Volume flow rate handled by the compressor in m3/s
(iii) Compressor discharge temperature if the enthalpy of refrigerant at compressor exit is 209.41 kJ/kg
(iv) Pressure ratio
(v) Heat rejected to the condenser in kW
(vi) Flash gas percentage after throttling
(vii) COP
(viii) Power required to drive the compressor. 20

Saturated values of properties of R-12:

Temperature	*Pressure*	*Sp. enthalpy (Saturated liquid)*	*Sp. enthalpy (Saturated vapour)*	*Sp. entropy*	*Volume*
(°C)	(bar)	h_f (kJ/kg)	h_g (kJ/kg)	(kJ/kg-K)	(m^3/kg)
–10	2.1912	—	183.19	0.7019	0.077
40	9.6066	74.59	203.981	—	—

Enthalpy values of vapour refrigerant at 9.6066 bars:

Temperature (°C)	*Sp. enthalpy* (kJ/kg)
40	203.981
50	210.950

(b) How does absorption refrigeration system differ from vapour compression system? 10

(c) What are the different types of compressors used in vapour compression plants? What are their limitations? 10

7. (a) The following data relate to a small gas axial turbine of a small turbojet unit:
Turbine inlet temperature, T_{01} =1100K
Turbine inlet pressure, P_{01} =4 bars
Pressure ratio, (stage) P_{01} / P_{03} = 1.873
Blade mean speed = 340 m/s
Mean radius of rotating blade ring = 0.216 m
Blade height = 0.0612 m
For gas, take C_P =1.148 kJ/kg/K and γ = 1.333
Assuming isentropic efficiency of stage (total to total) as 0.9, flow coefficient as 0.8 and flow enters the jet nozzle without swirl from turbine, calculate
(i) direction of absolute and relative velocity vector at entry and exit of rotor with axial direction and *(ii)* loading coefficient and degree of reaction. 20

(b) Mentioning the requirements of pulverized coal burners, explain the types of burners used for efficient utilization of different kinds of coal. 10

(c) In context of a power plant, explain the following: 10

(i) Load curve
(ii) Load duration curve
(iii) Load factor
(iv) Plant factor
(v) Reserve factor

8. (a) Explain the working principle of a supercritical boiler with the help of a diagram. What are the advantages of a supercritical boiler? 20

(b) What are the various locations of ID and FD fans for producing draught? Discuss them. 10

(c) Diesel plants are used as standby units in a grid system. Explain why. A power station supplies the following loads to consumers:

Time (hr)	0-6	6-9	9-12	12-16	16-20	20-22	22-24
Load (MW)	20	50	60	50	80	70	40

(i) Find the load factor of the plant.

(ii) What is the load factor of a standby plant of 30 MW capacity, if it takes up all the loads above 50 MW? 10