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

Neat sketches may be drawn, wherever required.

SECTION A

1. (a) Design a set of stepped pulleys to drive a machine from a countershaft that runs at 220 r.p.m, The centre distance between the two sets of pulleys is 2 m. The diameter of the smallest step on the countershaft is 160 mm. The machine is to run at 80 r.p.m., 100 r.p.m. and 130 r.p.m., and should be able to rotate in either direction. Find the length of the belt required for both the cases. 8

(b) What is the chief difference between heat-treatable and non-heat-treatable alloys? 8

(c) A bar of length L, material density S and modulus of elasticity E is rotating about one end with an angular speed of ω radians per second. Find the maximum stress set up in the bar and its extension due to rotation. 8

(d) The end of a rod made of mild steel is sliding over the unlubricated surface of hardened tool steel with a load of 100 kg. The hardness of mild steel is 15 HB. What is the distance travelled to produce a wear volume of 1 mm^3 by adhesive wear of the mild steel rod? 8

(e) Give a neat sketch of a unit cell of copper. Indicate Miller indices for its slip plane and slip direction. Why is copper so ductile? 8

2. (a) A simple beam supports a concentrated downward force P at a distance a from the left support. The flexural rigidity EI is constant. Find the equation of the elastic curve by successive integration. 20

(b) A vertical shaft is held in long bearings and a disc is attached to the shaft at its midpoint. The centre of gravity of the disc does not coincide with the axis of the shaft. Determine (i) the critical speed of the shaft and (ii) the range of the speed over which it is unsafe to run the shaft.

The diameter of the shaft is 15 mm and the span of the shaft between the bearings is 1 m. The mass of the disc is 10 kg and the centre of gravity of the disc is 0.3 mm from the axis of the shaft. Take E = 200 GN/mm^2 and permissible stress in the shaft material is 70×10^6 N/mm^2. 10

(c) Explain the phenomenon of interference in involute gears. What are the

conditions to be satisfied in order to avoid interference? List the important physical characteristics of a good bearing material. 10

3. (a) A two-span continuous beam is clamped at one end and simply supported at two other points. Determine the reactions caused by the application of a uniformly distributed load W_a; EI for the beam is constant. 20

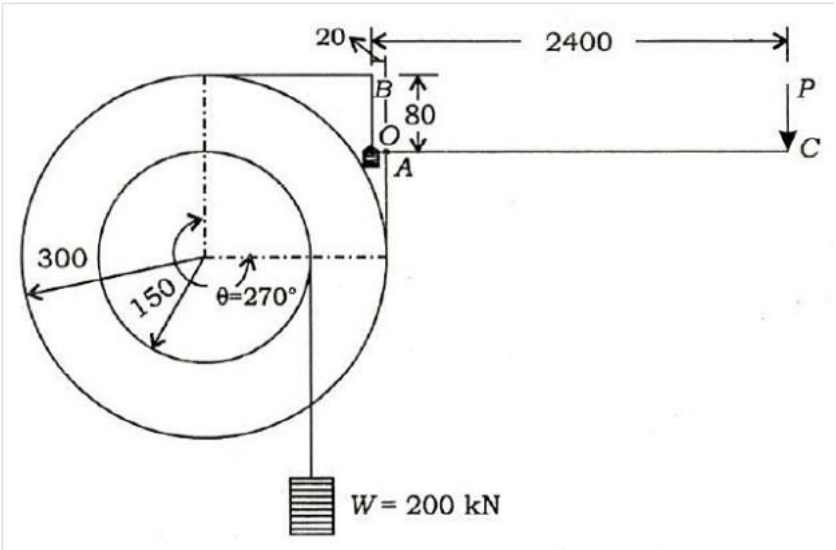
(b) Determine the composition in atoms percent of an alloy that consists of 97 wt% aluminium and 3 wt% copper. 10

(c) A solid cylindrical ceramic part is to be made whose final length must be $L = 25$ mm. It has been established that for this material, linear shrinkages during drying and firing are 9% and 5% respectively. Based on the dried dimension L_d, calculate (i) the initial length L_0 of the part and (ii) the dried porosity P_d, if the porosity of the fired part P_f is 4%. 10

4. (a) The bearings A and B of a shaft are 5 m apart. The shaft carries three eccentric masses C, D and E which are 160 kg, 170 kg and 85 kg respectively. The respective eccentricity of each mass measured from axis of rotation is 0.5 cm, 0.3 cm and 0.6 cm, and distance from A is 1.3 m, 3 m and 4 m respectively. Determine the angular position of each mass with respect to C so that no dynamic force is exerted at B and also find dynamic force at A for this arrangement when the shaft runs at 100 r.p.m. 20

(b) Draw a neat sketch of the Time-Temperature-Transformation diagram and enlist its salient points. 10

(c) The following figure shows a barrel and a differential band brake which are keyed to the same shaft. A rope is wound round the barrel and supports a load of 200 kN. The brake drum diameter is 600 mm and diameter of the barrel is 300 mm. The two ends of the band are attached to pins on opposite sides of the fulcrum of the brake lever at a distance of 20 mm and 80 mm respectively. The angle of contact of band brake is 270° and the coefficient of friction is 0.25. Determine the minimum force required at the end of the lever to support the load, if the length of the lever from the fulcrum is 2400 mm. 10



SECTION—B

5. (a) Under what circumstances would you use PERT as opposed to CPM in project management? Name a few projects where each would be more suitable than

other. 8

(b) In a slab milling operation with straight teeth cutter, the cutter has 15 teeth with 10° rake angle and rotates at 200 r.p.m. The diameter of the cutter is 80 mm and table feed is 75 mm/min, the depth of cut is 5 mm, the width of slab is 50 mm and ultimate shear stress of work material is 420 N/mm^2. Assuming the coefficient of friction between chip and cutter to be 0.7 and using Lee and Shaffer relation, plot variation of resultant torque and cutter rotation, and estimate average power consumption. 8

(c) An extruder screw with a thread angle of 20° has a melt pumping zone that is 1 m long, with a channel depth of 7 mm for a 50 mm diameter barrel. The screw is used to extrude 5 mm diameter circular nylon bars through a die with a 20 mm land length at 573 K. If the extruder is operated at 50 r.p.m. = 0.833 rev/s, determine the extruder and the characteristics, and obtain the operating flow rate. What is the speed of material leaving the extruder? Ignore die swell. 8

(d) Estimate the limiting drawing ratio (LDR) that you would expect from a sheet metal when stretched by 23% in length, decreases thickness by 10%. 8

(e) Why do we need inventory? Explain why we need to optimize the order quantity. The demand for a component is 10000 pieces per year. The cost per item is Rs 50 and the interest cost is 1% per month. The cost associated with placing an order is Rs 240. What is the EOQ? 8

6. (a) Consider the simple one-dimensional open-loop and closed-loop control systems illustrated in the figure shown below. Assume that the worktable mass m is known and that control is achieved by changing the force applied to the worktable through a torque to the gear. If the system is frictionless, develop equations for the force needed to obtain a new position for (i) open-loop control and (ii) closed-loop control, where both position and velocity are measured. 10

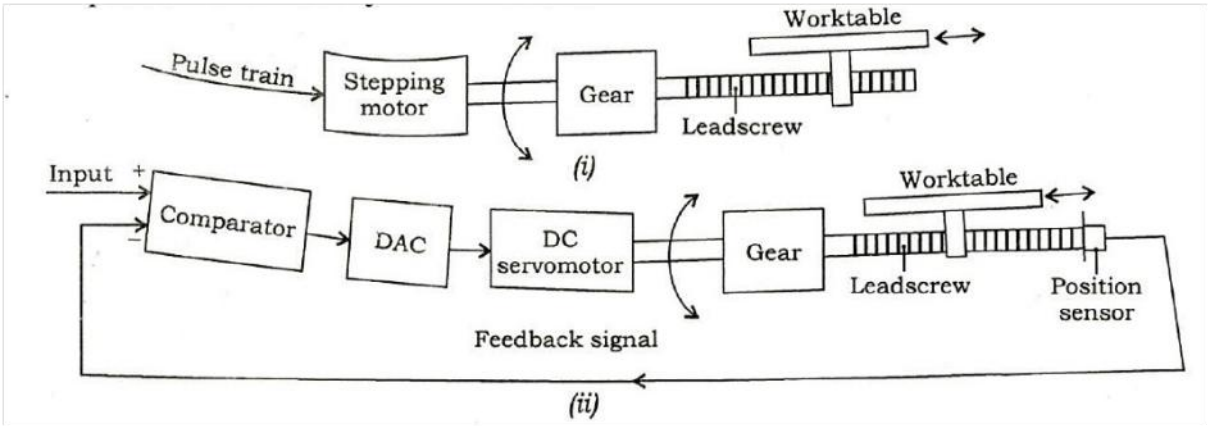


Fig. ; Schematic illustration of the components of
(i) an open-loop and (ii) a closed-loop control system

(b) A round rod of annealed brass 70-30 is being drawn from a diameter of 6 mm to 3 mm at a speed of 0.6 m/s. Assume that the frictional and redundant work together constitutes 35% of the ideal work of deformation. Calculate (i) power required in this operation and (ii) die pressure at the exit of the die. 10

(c) A lathe machine is targeted to produce shafts of 25 mm diameter. This conventional lathe is having process dispersion of 0.15 mm. Determine the following: 10

(i) How many shafts the machine is producing below 24.9 mm?
(ii) How many shafts the machine is producing above 25.2 mm?
(iii) Normally the machine does produce shafts in what range?

(iv) If the acceptable limit of shafts by consumer is 25 + 0.35 mm, how many defective shafts the machine will produce?

(d) The bore of an alloy steel component is to be finish broached to $31.75^{+0.01}$ mm diameter. The bore prior to broaching being $31.24^{+0.05}$ mm diameter, calculate (i) pitch of teeth, (ii) length of cutting portion and (iii) force to pull broach through work, if the length of hole = 25 mm, $t = 0.025$ mm, $k = 5000$ N and $S = 5$. Sketch the broach. 10

7. (a) Use dual simplex method to

Maximize $Z = -3x_1 - 2x_2$

subject to

$$x_1 + x_2 \geq 1$$
$$x_1 + x_2 \leq 7$$
$$x_1 + 2x_2 \geq 10$$
$$x_2 \leq 3,\ x_1, x_2 \geq 0$$

10

(b) What are the various charts used for process control of SQC? Discuss the relative advantages and disadvantages of use of control charts. 10

(c) A company is specialized in the manufacture of small-capacity motors. The structure cost of a motor is given below:

Material = Rs 50; Labour = Rs 80; Variable overhead = 75% of labour cost; Fixed overhead of the company is Rs 2,40,000; Sale price of each motor = Rs 230.

(i) Determine the breakeven point.

(ii) Calculate the number of motors to be sold to make a profit of Rs 1,00,000.

(iii) In case the sale price of each motor is reduced by Rs 15, then determine the number of motors to be sold to obtain breakeven point. 20

8. (a) Given an old forecast of Rs 250 lakh initially, compare the difference between smoothing constants $\alpha = 0.5$ and $\alpha = 0.10$ for the following series of 10 observations of sales of M/s. Smith & Co.: 10

(Rs in Lakh)

Series : 290, 290, 220, 270, 240, 230, 280, 240, 290 and 210

(b) Compare the working principles of Laser Beam Machining and Electron Beam Machining with the help of neat diagrams. 10

(c) Explain 'FAST' with the help of diagram and discuss it with respect to Value Engineering. 10

(d) What are MRP objectives? What are various lot sizes used for MRP? 10

MECHANICAL ENGINEERING Paper—II

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QUESTION PAPER SPECIFIC INSTRUCTIONS

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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

Q1. (a) Derive the following thermodynamic relation : 10

$$c_p - c_v = -T\left(\frac{\partial v}{\partial T}\right)_p^2 \left(\frac{\partial p}{\partial v}\right)_T$$

(b) Discuss the effect of the following on the flame speed during combustion in an SI engine : 10

(i) Compression ratio
(ii) Intake pressure
(iii) Engine speed
(iv) Air-fuel ratio
(v) Engine load

(c) A copper wire having a diameter of 2 mm is exposed to a convection environment with heat transfer coefficient, h = 5000 W/m²-K and environment temperature, T_∞ = 100°C. What current must be passed through the wire to produce a centre temperature of 150°C? Specific electrical resistance of copper is 1.67 μΩ cm. Thermal conductivity of copper is 386 W/m-K. 10

(d) The following data are given for a single cylinder four stroke cycle oil engine : Cylinder diameter = 18 cm, stroke = 36 cm, speed of the engine = 286 rpm, brake torque = 375 Nm, IMEP = 7 bar, fuel consumption = 3.85 litres/hr, specific gravity of fuel = 0.8, calorific value of fuel = 44.5 MJ/kg. A/F = 25 : 1, ambient air temperature = 21°C, c_p of gases = 1.2 kJ/kg-K, exhaust gas temperature = 415°C, cooling water circulated = 4.2 kg/min, rise in temperature of cooling water = 28.5°C. Find the mechanical and indicated

thermal efficiency and draw a heat balance sheet on percentage basis. 10

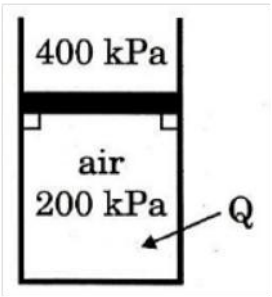
Q2. (a) The readings of two thermometers A and B agree at ice point and steam point as 0°C and 100°C. The two temperature readings are related by the following expression :

$$t_A = a + bt_B + ct_B^2$$

where a, b and c are constants. In a constant temperature bath, the temperatures are shown as 51°C on thermometer A and 50°C on thermometer B. Determine the reading on thermometer B when the thermometer A reads 65°C. Can you comment which of the two thermometers is correct? 20

(b) A 40 kg rigid steel tank of 1000 litre capacity contains air at 500 kPa pressure and both tank and air are at 20°C temperature. The tank is connected to a line flowing air at 2 MPa pressure and 20°C temperature. The valve is opened, allowing air to flow into the tank until the pressure reaches 1.5 MPa and it is then closed. Assume the air and tank are always at the same temperature and the final temperature is 35°C. Find the final air mass that entered the tank and the heat transfer. Specific heat of steel = 0.46 kJ/kg-K. 20

Q3. (a) A piston-cylinder device is shown in the figure. The piston resting on top of a set of stops, initially contains 3 kg of air at 200 kPa and 27°C temperature. The mass of piston is such that a pressure of 400 kPa is required to move it. Heat is now transferred to the air until the volume is doubled. Determine the work done by the air and the amount of heat transfer, and show the process on P-v diagram. The average c_p for air is 0.8 kJ/kg-K, which remains constant throughout any process. 20



(b) A petrol engine having stroke volume of 0.0012 m^3 and compression ratio of 5.5 compresses the mixture to 8.5 bar and 350°C. Ignition is started so that the pressure rises along a straight line during explosion and attains its higher value of 28 bar after the piston has travelled l/30 of working stroke. The air-fuel ratio is 16 : 1. Calorific value of the fuel is 44 MJ/kg and c_p = 0.962 kJ/kg-K. Find the heat loss per kg of charge during explosion. 20

Q4. (a) Derive the following expression for the thermal efficiency of an air standard diesel cycle : 20

$$\eta_{th} = 1 - \frac{1}{\gamma} \cdot \frac{1}{r^{\gamma-1}} \cdot \left(\frac{\rho^{\gamma} - 1}{\rho - 1} \right)$$

r = compression ratio; ρ = cut-off ratio, $\gamma = c_p/c_v$.

(b) Calculate the proportion of the heat of fuel carried away by the flue gases for the following data :

Coal with CV of 29.6 MJ/kg of coal has a composition by mass C = 78%, H =

5%, O_2 = 8%, S = 2%, N_2 = 2% and remainder is ash. It is burnt in a furnace with 50% excess air. The flue gases leaving the chimney are at 327°C and the atmospheric temperature is 15°C. Assume perfect combustion. The specific heat, c_p, for air and dry products is 1005 J/kg-K and 1045 J/kg-K respectively. The heat carried away per kg of moisture in the flue gases is 2990 kJ/kg. Composition of air by mass O_2 = 23% and N_2 = 77%. 20

SECTION B

Q5. (a) Air at 20 kPa and 5°C temperature enters a 25 mm diameter tube at a velocity of 1.5 m/s. Using a flat-plate analysis, estimate the distance from the entrance at which the flow becomes fully developed.
Viscosity, $\mu = 1.864 \times 10^{-5}$ Pa-s. 10

(b) Five grams of water vapour per kilogram of atmospheric air at 35 °C dry bulb temperature and 60% relative humidity is removed and the dry bulb temperature of air after removing the water vapour becomes 25°C. Find for the air at final stage
(i) the relative humidity, and
(ii) the dew point temperature.
Assume, condition of atmospheric air is 35°C dry bulb temperature and relative humidity is 60%. Atmospheric pressure is 100 kPa.
The saturation properties of water are given in the following table : 10

Temp, °C	5	10	15	20	25	30	35	40
Sat. pressure, kPa	0.87	1.23	1.71	2.34	3.17	4.25	5.63	7.38

(c) Define blade efficiency (η_b) of a single stage steam turbine and prove that the maximum blade efficiency for a single stage steam turbine, $(\eta_b)_{max} = \cos^2 \alpha$, where α is the blade inlet angle. 10

(d) A solid sphere of diameter 10 cm is heated to 1000°C and suspended in a room having room temperature of 30°C. Compute the time taken by the sphere to cool to 500°C assuming emissivity of sphere 0.1 and density 8.68 gm/cc. Take specific heat = 0.098 J/kg-K. 10

Q6. (a) Air at 200 kPa pressure and 200°C is heated as it flows through a tube with a diameter of 25 mm at a velocity of 10 m/s. Calculate the heat transfer per unit length of tube, if a constant-heat-flux condition is maintained at the wall and the wall temperature is 20 °C above the air temperature, all along the length of the tube. How much would the bulk temperature increase over a 3-m length of the tube? For air at 200°C temperature: viscosity, $\mu = 2.57 \times 10^{-5}$ Pa-s, thermal conductivity, k = 0.0386 W/m-K, constant specific heat, c_p = 1025 J/kg-K. 20

(b) A long cylinder having a diameter of 2 cm is maintained at 600°C and has an emissivity of 0.4. Surrounding the cylinder is another long, thin-walled concentric cylinder having a diameter of 6 cm and an emissivity of 0.2 on both the inside and outside surfaces. The assembly is located in a large room having a temperature of 27°C. Calculate the net radiant energy lost by the 2-cm-diameter cylinder per metre of length. Also calculate the temperature of the 6-cm-diameter cylinder.
Stefan-Boltzmann Constant, $\sigma = 5.67 \times 10^{-8}$ W/m^2-K^4. 20

Q7. (a) A 25 TR capacity ammonia vapour compression refrigerating machine works

between 26°C and –20°C. The ammonia leaves the compressor dry and saturated. Liquid ammonia is undercooled to 22.5°C, before throttling. Find the theoretical COP of the machine. The c_p of saturated ammonia liquid is 4.72 kJ/kg-K. The c_p for ammonia vapour is 2.8 kJ/kg-K. Find the COP of the cycle and the mass flow rate of ammonia in kg/min. 20

	Liquid		Vapour	
t,°C	h, kJ/kg	s, kJ/kg-K	h, kJ/kg	s, kJ/kg-K
26	322.5	1.4248	1448.0	5.3076
–20	108.6	0.6538	1437.6	5.9041

(b) An open cycle gas turbine plant operates with a pressure ratio of 4.5 while using 82 kg/min of air and 1.4 kg/min of fuel. The net output of the plant is 200 kW when 230 kW is needed to drive the compressor. Air enters the compressor at 100 bar and 15°C and combustion gases enter the turbine at 765°C. Assuming specific heat of air and combustion gases as 1.005 kJ/kg-K and 1.128 kJ/kg-K respectively, the index of compression 1.4, the index of expansion 1.34 and mechanical efficiency for both the compressor and turbine as 0.98, estimate

(i) the isentropic efficiency of the compressor,

(ii) the isentropic efficiency of the turbine, and

(iii) the overall efficiency of the plant. 20

Q8. (a) Steam flows from the nozzles of a single row impulse turbine with a velocity of 450 m/s at a direction which is inclined at an angle of 16° to the peripheral velocity. Steam comes out of the moving blades with an absolute velocity of 100 m/s in the direction at 110° with the direction of blade motion. The blades are equiangular and the steam flow rate is 6 kg/s. Determine the power loss due to friction. 20

(b) State Buckingham π-theorem and hence obtain an expression for the thrust developed by a propeller which μi, density ρ, propeller diameter D and the compressibility of the medium measured by the local velocity of sound c. 20