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'

1. Answer any four of the following (each answer should conform to a limit of 150 words):

(a) (i) In a four-bar mechanism, S and L are the lengths of the shortest and the longest links, P and Q are the lengths of the remaining links. State the condition for at least one link to make a full revolution. Sketch and name the mechanism. 5

(ii) Define pressure angle in a cam-follower and state its importance. Show it on a sketch. 5

(b) (i) What are the requirements of static equivalence & dynamic equivalence in single-cylinder-engine balancing? 5

(ii) Draw the stress-strain diagram for a low-carbon-steel and show on it various events. 5

(c) (i) Two beams of equal lengths 'l', one as a simply supported and the other as a cantilever, are loaded at the centre with a concentrated load of W. Draw the shear force, B.M. and deflection diagrams, indicating the maximum values. 5

(ii) Distinguish between strut and column. Name two important buckling equations indicating the range of slenderness-ratio for their applicability. 5

(d) (i) Draw the iron-carbon phase-diagram indicating the existence of different phases. 5

(ii) Draw the T-T-T curves and show the important heat-treatment operations on it. 5

(e) (i) Name three structures that occur as a result of arrangement of atoms in aggregates of atoms in aggregates and state their characteristics. 5

(ii) Explain in brief the strain hardening. 5

2. (a) Between a solid mass of 10 kg and the floor are kept two slabs of isolators - natural rubber slab and felt in series. The rubber slab has a stiffness of 3000 N/m and equivalent viscous damping coefficient of 100 N-sec/m. The felt has a stiffness of 12000 N/m and an equivalent damping coefficient of 330 N-sec/m. Determine the undamped and damped natural frequencies of the system in vertical direction. 15

(b) A pinion having 20 teeth of 5 mm module, rotates at 200 rpm and transmits 1.5 kW to a gear-wheel having 50 teeth. The tooth form is 20 involute of standard-dimensions. Find (a) the length of path of contact and arc of contact, (b) the normal force between the teeth for the pitch-point contact. Deduce the equations used. 15

(c) The minute hand on Big Ben, weighs 15 kg and is 3 m long. Its C.G. is 1.2 m from the pivot. Calculate the M.R. (mass × radius) product and angular position needed to statically balance this link and design the counterweight positioned at 300 mm from the centre. 10

3. (a) A compound cylinder is formed with inner diameter = 300 mm; the diameter at the junction = 400 mm and outer diameter = 500 mm. If the initial interference in diameters at the junction is 0.2 mm, find the radial pressure developed at the junction. Find also the minimum temperature to which the outer cylinder is to be heated to slip it onto the inner cylinder. Take E = 2×10^5 N/mm^2 and $\alpha = 12.5 \times 10^{-6}$/°C. 20

(b) The bracket shown in Figure 1 is subjected to a horizontal force P of 8 kN. Determine the stresses at points A and B. 10

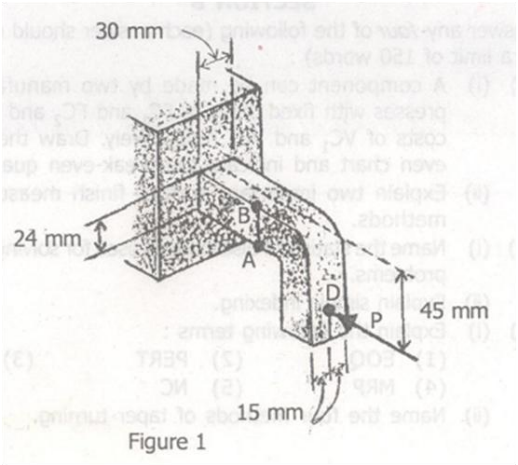

Figure 1

(c) During a routine manufacturing operation, a rod AB of 20 mm diameter and 1.5 m long, must acquire an elastic strain-energy of 13.6 N-m. Using E = 200 GPa, determine the yield stress of steel, if the factor of safety with respect to the permanent deformation is to be five. 10

4. (a) A 70 kW-engine runs at a speed of 2 rps. Due to the operational constraints the fluctuation of speed should not exceed 1% of the mean speed. The radius of gyration of the fly-wheel is 1 m. The fluctuation of energy from the turning moment diagram is found to be 34000 N-m. Find the mass of the fly-wheel. 10

(b) A flat belt is installed with an initial tension of 2.5 kN. The coefficient of friction between the pulley and the belt is 0.3. The angle of lap on the smaller pulley is 16.5° and belt-speed is 18 m/s. Determine the maximum power that the belt can transmit. Assume the belt is perfectly elastic and without mass. 10

(c) Name the five types of additive agents in plastics and state their purpose. 10

(d) What are the advantages and limitations of the use of composite materials in engineering applications. 10

SECTION 'B'

5. Answer any four of the following (each answer should conform to a limit of 150 words):

(a) (i) A component can be made by two manufacturing presses with fixed costs of FC_1 and FC_2 and variable costs of VC_1 and VC_2 respectively. Draw the break-even chart and indicate the break-even quantity. 5

(ii) Explain two important surface finish measurement methods. 5

(b) (i) Name the statistical distributions used for solving queing problems. 5

(ii) Explain simple indexing. 5

(c) (i) Explain the following terms: 5

(1) EOQ (2) PERT (3) CPM (4) MRP (5) NC

(ii) Name the four methods of taper turning. 5

(d) (i) What is rake angle and what is its importance in metal cutting? 5

(ii) How much is the tool-wear with respect to the work material (Die steel) in case of ECM and EDM? 5

(e) (i) Write the flow chart and pseudocode for finding the maximum of a set of three numbers. 5

(ii) Distinguish between general purpose programming languages and special purpose simulation languages. 5

6. (a) Describe the working of a 3-High Rolling Mill. Indicate the movements of rolls and the workpiece. 10

(b) Why is shear provided on a punch? Indicate the single shear and double shear on a punch. 10

(c) During orthogonal cutting of mild steel the following data was observed:
Cutting speed v = 30 m/min
Width of chip b = 4 mm
Thickness of chip t = 0.25 mm
Rake angle $\alpha = 20°$
Cutting force $F_N = 1135$ N
Normal force $F_V = 110$ N
Draw the Merchant diagram. Determine the friction angle and the shear angle. 20

7. (a) Distinguish between the flash and gutter with the help of a neat sketch. Why is it easier to forge a thick shape than a thin shape? 10

(b) What is the function of clearance in blanking operation? Indicate with the help of a diagram, the die and punch set for making a 20 mm dia blank. 10

(c) A product is sold at a rate of 500 pieces per day and is manufactured at a rate of 2500 pieces a day. The set-up cost of the machine is Rs. 1000 and the storage cost is Rs. 3.20 per piece, material cost is Rs. 2.10 per piece and overhead cost is Rs. 4.00 per piece. If the interest charges are 8%, find the minimum cost batch size and the cost of the production run. Derive the equation used. 20

8. (a) The standard weight of a block is 5 kg and it contains sand and cement. The sand costs Rs. 0.05 per kg and cement costs Rs. 0.08 per kg. The block to be strong must not contain more than 4 kg of sand and must contain less than 2 kg of cement. What is the minimum cost of the block? 10

(b) What are the different codes used in NC programming for NC machine tools? 10

(c) Write the NC codes for the following operations: 20

(i) Linear interpolation;
(ii) Circular interpolation counter-clockwise rotation
(iii) Dwell
(iv) Hold/Delay
(v) Thread-cutting
(vi) End of programme
(vii) Spindle on clockwise rotation
(viii) Tool-change
(ix) Coolant supply No. 1 on
(x) Coolant supply off

MECHANICAL ENGINEERING Paper II

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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/cm^2 = 0.98 bar

1 bar = 10^5 pascals

Universal gas constant = 8314.6 J/kmol-K

Psychrometric chart is enclosed.

SECTION—A

1. Answer any four parts:

(a) The only way in which heat can be transferred from a Carnot engine in outer space is by radiation. The rate at which heat is radiated is proportional to the fourth power of the absolute temperature T_2 and to the area of the radiating surface. Show that for a given power output and a given T_1, the area of the radiator will be minimum when $T_2/T_1 = 3/4$. 10

(b) Two reversible heat engines A and B are arranged in series A rejecting heat directly to B. Engine A receives heat 200 kJ at a temperature of 421 °C from a heat source, while engine B is in communication with a cold sink at a temperature of 4.4°C. If the work output of A is twice that of B, find (i) the intermediate temperature between A and B, (ii) the efficiency of each engine and (iii) the heat rejected to the cold sink. 10

(c) Prove the Mayer relation $C_P - C_V = (vT\beta^2) / \alpha$
where α = isothermal compressibility and β = coefficient of volume expansion. 10

(d) Temperature profile for heat conduction through a wall of constant thermal conductivity is a straight line, prove that it becomes parabolic in the presence of a heat source. 10

(e) What is meant by abnormal combustion? Explain with appropriate diagrams the phenomenon of knock in SI engines. 10

2. (a) Two identical bodies of constant heat capacity C at temperatures T_1 and T_2 respectively, are used as reservoirs for a heat engine. If the bodies remain at constant pressure and undergo no change of phase, show that the amount of work obtainable is $W = C(T_1 + T_2 - 2T_f)$
where T_f = final temperature attained by both the bodies.
Also, show that for maximum work output, $T_f = \sqrt{(T_1.T_2)}$ 8

(b) Derive four Maxwell relationships. 10

(c) A heat pump is to be used to heat a house in winter and then reversed to cool the house in summer. The interior temperature is to be maintained at 20 °C. Heat transfer through the walls and roof is estimated to be 0.525 kJ/ sec per degree temperature difference between the inside and the outside.

(i) If the outside temperature in winter is 5 °C, what is the minimum power required to drive the heat pump?

(ii) If the power input is the same as in part (i), what is the maximum outer temperature for which the inside can be maintained at 20 ° C? 10

(d) A mass of 6.98 kg of air is in a vessel at 200 kPa, 27 °C. Heat is transferred to the air from a reservoir at 727 °C until the temperature of air rises to 327 °C.
The environment is at 100 kPa, 17 °C. Determine (i) the initial and final availability of air and (ii) the maximum useful work associated with the process. 12

3. (a) A four-cylinder, four-stroke square engine running at 40 rev/sec is with a carburettor which is required to supply 5 kg of air and 0.5 kg of fuel per minute. The fuel specific gravity is 0.75. The air is initially at 1 bar and 300 K. Calculate the throat diameter of the choke for a flow velocity of 100 m/sec. Velocity coefficient is 0.8. If the pressure drop across the fuel metering orifice is 0.80 of that of choke, calculate the orifice diameter assuming C_{df} = 0.60 and γ = 1.4. If the carburettor venturi has a 3 cm throat, assuming the bore to be 10 cm, volumetric efficiency of 75%, the density of air to be 1.15 and coefficient of airflow to be 0.75 , calculate the suction at the throat. 15

(b) A four-cylinder, four-stroke diesel engine develops a power of 180 kW at 1500 r.p.m. The brake specific fuel consumption (bsfc) is 0.2 kg/kWh. At the beginning of injection, pressure is 30 bar and the maximum cylinder pressure is 50 bar. The injection is expected to be at 200 bar and maximum pressure at the injector is set to be about 500 bar. Assume the following:
C_d for injector = 0.7
SG of fuel = 0.875
Atmospheric pressure = 1 bar
Effective pressure difference = Average pressure difference over the injection period.
Determine the total orifice area required per injector if the injection takes place over 15° crank angles. 10

(c) A four-stroke cycle gas engine has a bore of 20 cm and a stroke of 40 cm. The compression ratio is 6. In the test on the engine the indicated mean effective pressure is 5 bar, the air to gas ratio is 6 : 1 and the calorific value of the gas is 12 MJ/m^3 at NTP. At the beginning of the compression stroke, the temperature is 77°C and pressure 0.98 bar. Neglecting residual gases, determine the indicated power, the thermal efficiency and the relative efficiency of the engine at 250 r.p.m. 10

(d) Explain the mechanism of smoke formation in an IC engine. 5

4. (a) Define shape factor.
A concentric of blackbody spheres is formed when a small sphere is located at the geometric centre of a large hollow sphere. The temperature of the outer surface of the small sphere is 600 K while the inner surface temperature of large sphere is 300 K. The outside diameter of the small sphere is 10 cm and the inside diameter of the large sphere is 50 cm. Calculate the following:

(i) The net interchange of heat between the two spheres.

(ii) The percentage of emission from the inner surface of the large sphere which is absorbed by the small sphere.

(iii) The percentage of emission from the inner surface of the large sphere which is absorbed by itself. 9

(b) The inner surface at r = a and the outer surface at r = b of a hollow cylinder are maintained at uniform temperatures of T_1 and T_2 respectively. The thermal conductivity k of the solid is constant.
Develop an expression for the one-dimensional steady-state temperature distribution T(r) in the cylinder. Also, develop an expression for the radial heat flow rate Q through the cylinder over a length H. 10

(c) (i) Differentiate among kinematic viscosity, thermal diffusivity and diffusion coefficient. Show that they have the same units. 5

(ii) Estimate the rate of evaporation of toluene from the bottom of a deep, narrow cylindrical vessel to air at 291.7 K flowing over the top surface of the vessel. The diffusivity of air toluene vapour is 0.826×10^{-5} m^2/sec and the saturated vapour pressure of toluene at the liquid surface in the vessel is 0.026 atm. Take the distance between the liquid toluene surface and the top of the vessel as 1.525 m, given

R = 0.08205 m^3-atm/(kg-mol-K) 10

(d) Define and explain the significance of the following dimensionless numbers: 6

(i) Grashof No. (ii) Nusselt No. (iii) Prandtl No.

SECTION—B

5. Answer any four parts:

(a) With the help of a neat sketch, explain the working principle of continuous vapour absorption system. 10

(b) Prove that the change of entropy for any process can be expressed as an equality of the form

$$ds = \frac{\delta Q}{T} + \frac{\delta(LW)}{T}$$

where terms have their usual meanings and LW = Lost Work. 10

(c) Explain, with the help of a sketch, the working of a modern high pressure, high duty boiler. 10

(d) (i) Discuss the merits and demerits of using pre-whirl at inlet to a centrifugal compressor. 5

(ii) Explain the merits and demerits of vaned and vaneless diffusers used in centrifugal compressors. 5

(e) A radiation shield having an equal emissivity ε_3 on both its surfaces is placed between two large parallel plates at T_1 and T_2 K with emissivities $\varepsilon_1 = 0.8$ and $\varepsilon_2 = 0.5$. Calculate the emissivity of the radiation shield in order to reduce the heat transfer between the plates to 8 percent of that without the radiation shield. 10

6. (a) Define Effective temperature, Dry-bulb temperature and Dew-point temperature, and explain Adiabatic saturation process. 8

(b) A Lithium Bromide-Water vapour absorption refrigeration system has a capacity of 10 TR and has the following details:

Evaporator temperature 2°C, the circulating cooling water in the condenser absorbs heat at 30°C, steam at 3 bar and 0.85 dry is used as the heat source in the generator and leaves the generator as saturated liquid at 2 bar. The concentrations of lithium bromide in the strong solution of refrigerant leaving the absorber for the generator and the weak solution of refrigerant entering into the absorber from the generator are 0.42 and 0.52 respectively. The specific enthalpy of binary mixture leaving the absorber for the generator and entering into the absorber from the generator are −22 kJ/kg and 55 kJ/kg respectively. The refrigerant leaves the evaporator as saturated vapour at 2 °C and leaves the generator as saturated vapour at the generator temperature at which steam supplying the heat condenser in the generator. The refrigerant leaves the condenser as saturated liquid at 30 °C. Find:

(i) the mass flow rates of strong solution of refrigerant entering the generator and weak solution of refrigerant leaving the generator;
(ii) the heat supplied in the generator per sec;
(iii) the heat rejection rate in the absorber and the condenser;
(iv) the COP of the plant and the maximum COP;
(v) the relative COP;
(vi) the consumption of steam per hour in the generator to supply heat.

Given that:

t_{sat} corresponding to 3 bar = 133.5 °C

h_g corresponding to 3 bar = 2724.7 kJ/kg
h_{fg} corresponding to 3 bar = 2163.2 kJ/kg
h_f corresponding to 30 °C = 125.7 kJ/kg
h_g corresponding to 2 °C = 2505.2 kJ/kg 32

7. (a) In an open-cycle gas turbine plant, the air is compressed in an axial flow compressor from inlet temperature of 288 K and stagnation pressure of 1 bar to stagnation pressure of 4 bar. There are two turbines. One is directly coupled to the compressor and the other (reheat turbine) is coupled to the generator. Similarly there are two combustion chambers prior to each turbine. The air at the outlet of compressor is heated to 864 K in a heat exchanger through which the exhaust gases from the reheat turbine are passing. The temperature of hot gases at the inlet to both turbines is 1100 K and isentropic efficiency of the compressor is 85%. Mechanical transmission efficiency is 99% and combustion efficiency of both combustion chambers is 98%.

The pressure losses in both combustion chambers are 2% of the chamber inlet pressure. The air-side pressure loss in the heat exchanger is 3% of the compressor delivery pressure while gas-side pressure drop is 0.04 bar. Take index of compression in the compressor to be 1.4 and that of expansion in both the turbines as 1.27. Specific heat value of air and gases may be taken as 1.005 and 1.147 kJ/kg-K respectively. Calculate:

(i) compressor work;
(ii) pressure-ratio of both turbines;
(iii) specific work output and work ratio;
(iv) heat exchanger effectiveness. 25

(b) Compare an axial flow compressor stage with that of a centrifugal machine with regard to flow rate, pressure rise and efficiency. 10

(c) Sketch the typical C_L and C_D variation with incidence and give reasons for the variation. 5

8. (a) Distinguish between Bin and Unit system of PF firing with sketches. 5

(b) Name the different methods of gas control schemes for superheat temperature control. 5

(c) Write short notes on: 8
(i) Supercritical boilers
(ii) Combined cycle power plant.

(d) What is circulation ratio? ID fan or FD fan; which one is larger in size and why? 3

(f) What do you understand by load factor and capacity factor? When are they numerically equal? 4

(g) Estimate the mass of flue gases flowing through the chimney as per data given below:
Draught produced = 20 mm of water column
Temperature of the flue gases = 573 K
Ambient temperature = 303 K
The mass of air used = 19 kg per kg of fuel burnt
Dia of the chimney = 2 m
Neglect losses. 10