MECHANICAL ENGINEERING

Paper I

Time Allowed : Three Hours | *Maximum Marks : 300*

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.*

*Questions No. **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.

Diagrams / Figures, wherever required, shall be drawn in the space provide for answering the question itself.

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

Psychrometric Chart is given on Page No. 46.

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.

*Answers must be written in **ENGLISH** only.*

SECTION A

Q1. (a) The velocity components in a two-dimensional incompressible flow are :

$u = 8x^2y - \frac{8}{3} y^3$ and $v = -8xy^2 + \frac{8}{3} x^3$.

Show that these velocity components represent a possible case of an irrotational flow. *12*

(b) (i) Carnot efficiency and 2nd law efficiency of a heat engine are 70% and 90% respectively. Determine the first law efficiency. *4*

(ii) A heat engine operates between two reservoirs at 800°C and 20°C. One-half of the work output of the engine is used to drive a Carnot heat pump that removes heat from the cold surroundings at 2°C and transfers it to a house maintained at 22°C. If the house is losing heat at a rate of 62,000 kJ/h, determine the minimum rate of heat supply to the heat engine required to keep the house at 22°C. *8*

(c) A hollow sphere of inside radius 3 cm and outside radius 5 cm is electrically heated at inner surface at a constant rate of heat flux of 10^5 W/m^2. The outer surface of the sphere dissipates heat to the surrounding air at 40°C. Assuming k = 15 W/mK for the sphere material and h = 400 W/m^2 K, calculate the inner and outer surface temperatures of the sphere. *12*

(d) A V-8 engine with 7·5 cm bores is redesigned from two valves per cylinder to four valves per cylinder. The old design had one inlet valve of 34 mm diameter and one exhaust valve of 29 mm diameter per cylinder. These are replaced with two inlet valves of 27 mm diameter and two exhaust valves of 2 mm diameter. If the maximum valve lift equals 22% of the valve diameter for all valves, calculate the increase of inlet flow area per cylinder. Also discuss the advantages and disadvantages of the new system. *6+6*

(e) Describe briefly the working principle of a vortex tube refrigeration system mentioning its advantages and disadvantages. *12*

Q2. (a) (i) Prove that equipotential lines and constant function streamlines are orthogonal to each other. *4*

How do you distinguish between developing flow and fully developed flow ? *2*

(ii) A spherical balloon having 3 m diameter weighs 130 N and contains helium having density of 0·22 kg/m^3, whereas the surrounding air has a density of 1·225 kg/m^3. The balloon is tied with the cable which is inclined to the ground. Determine the inclination of the cable to the ground when a wind of 5 m/s blows past the balloon. Take $C_D = 0{\cdot}2$. *14*

(b) A frictionless piston-cylinder device initially contains 0·01 m^3 of argon gas at 400 K and 350 kPa. Heat is now transferred to argon from a furnace at 1200 K, and the argon expands isothermally until its volume is doubled. The heat transfer takes place in such a way that there is no heat loss from argon to the atmosphere. The atmosphere is at 300 K. Determine (i) the work done by argon, (ii) the heat transferred to argon, and (iii) entropy generation and irreversibility during the process. *20*

Take R = 0·2081 kJ/kg-K for argon.

(c) Show that for fully developed laminar flow in a tube with a parabolic velocity profile $u = 2\,u_m \left[1 - \left(\frac{r}{R}\right)^2\right]$, the Nusselt number is $\frac{48}{11}$ if the wall temperature increases linearly with x. Symbols have their usual meanings. *20*

Q3. (a) (i) Prove that the total pressure which is the summation of static and dynamic pressure, also known as stagnation pressure, decreases in an irreversible adiabatic process when a gas is flowing in a steady flow device of constant cross-section without any work transfer. *6*

(ii) A heat engine operates between the maximum and minimum temperatures of 671°C and 60°C respectively, with an efficiency of 50% of its Carnot efficiency. It drives a heat pump which uses river water at 4·4°C to heat a block of flats in which the temperature is to be maintained at 21·1°C. Assume that a temperature difference of 11·1°C exists between the working fluid and the river water, on the one hand, and the required room temperature on the other. Also assume that the heat pump would be operated with a COP of 50% of the ideal COP. Find the heat input to the engine per unit heat output from the heat pump. *14*

(b) (i) A cubical oven has inner sides equal to 0·4 m. One of the faces of the oven forms the door. If the five other inside faces are black and maintained at 600°C, find the rate of heat loss if the oven door is kept open. *10*

Take Stefan constant $\sigma = 5{\cdot}67 \times 10^{-8}$ W/m^2 K^4.

(ii) Explain briefly why dropwise condensation is preferred to filmwise condensation. *10*

(c) In an air-conditioning system, the inside conditions are dry bulb temperature 25°C and relative humidity 50%. The outside conditions are dry bulb temperature 40°C and wet bulb temperature 27°C. The room sensible heat factor is 0·8. 50% of room air is rejected to atmosphere and an equal quantity of fresh air is added before air enters the air-conditioning apparatus.

Assuming fresh air is added at a rate of 100 m^3/minute, draw the process diagram and determine the following :

(i) Room sensible and latent heat load

(ii) Sensible and latent heat load due to fresh air

(iii) Apparatus dew point

(iv) Humidity ratio

Take density of air = 1·2 kg/m^3 at a pressure of 1·01325 bar and humid specific heat = 1·022 kJ/kg K. Bypass factor is zero. *20*

Q4. (a) (i) For the same compression ratio and heat rejection, show that the efficiency of Otto cycle is greater than Diesel cycle using T-s plot. *4*

(ii) An ideal gas is compressed reversibly and adiabatically from state a to state b. It is then heated reversibly at constant volume to state c. After expanding reversibly and adiabatically to state d such that $T_b = T_d$, the gas is again reversibly heated at constant pressure to state e such that $T_e = T_c$. Heat is then rejected reversibly from the gas at constant volume till it returns to state a. Show that $T_a = \frac{T_b^{\gamma+1}}{T_c^{\gamma}}$; where $\gamma = \frac{C_p}{C_v}$. *16*

(b) The following data refers to a single-stage vapour compression system :

Refrigerant used : R-134a

Condensing temperature = 35°C

Evaporator temperature = – 10°C

Compressor : rpm = 2800

Efficiency = 0·8

Clearance volume/Swept volume = 0·03

Swept volume = 269·4 cm^3

Expansion index = 1·12

Condensate subcooling = 5°C

Determine : (i) tonnage, (ii) power, (iii) COP of refrigeration and (iv) heat rejection to condenser. *20*

Properties of R – 134 a :

t, °C	P, bar	V_g, m^3/kg	h_f, kJ/kg	h_g, kJ/kg	s_f, kJ/kg K	s_g, kJ/kg K
– 10	2·014	0·0994	186·7	392·4	0·9512	1·733
35	8·870	–	249·1	417·6	1·1680	1·715

Assume : Specific heat of vapour at 8·87 bar is 1·1 kJ/kg K and that of liquid is 1·458 kJ/kg K. Suction vapour is dry saturated and compression process is isentropic. Compressor is single acting.

(c) A two-stroke single cylinder SI engine of 10 cm bore having compression ratio 8·5, consumes 15·75 kg/hr of fuel when running at 3500 rpm. The piston speed is 14 m/s and the indicated mean effective pressure is 5 bar. The A/F ratio is 15 : 1, the calorific value of the fuel is 44 MJ/kg. Assume 'R' for the mixture as 290 J/(kg K), the pressure and temperature of the mixture as 1·05 bar and 27°C respectively, η_{mech} = 85%.

Calculate : *20*

(i) The scavenging ratio

(ii) The scavenging efficiency

(iii) The trapping efficiency

(iv) The ip

(v) The bp

(vi) The brake thermal efficiency

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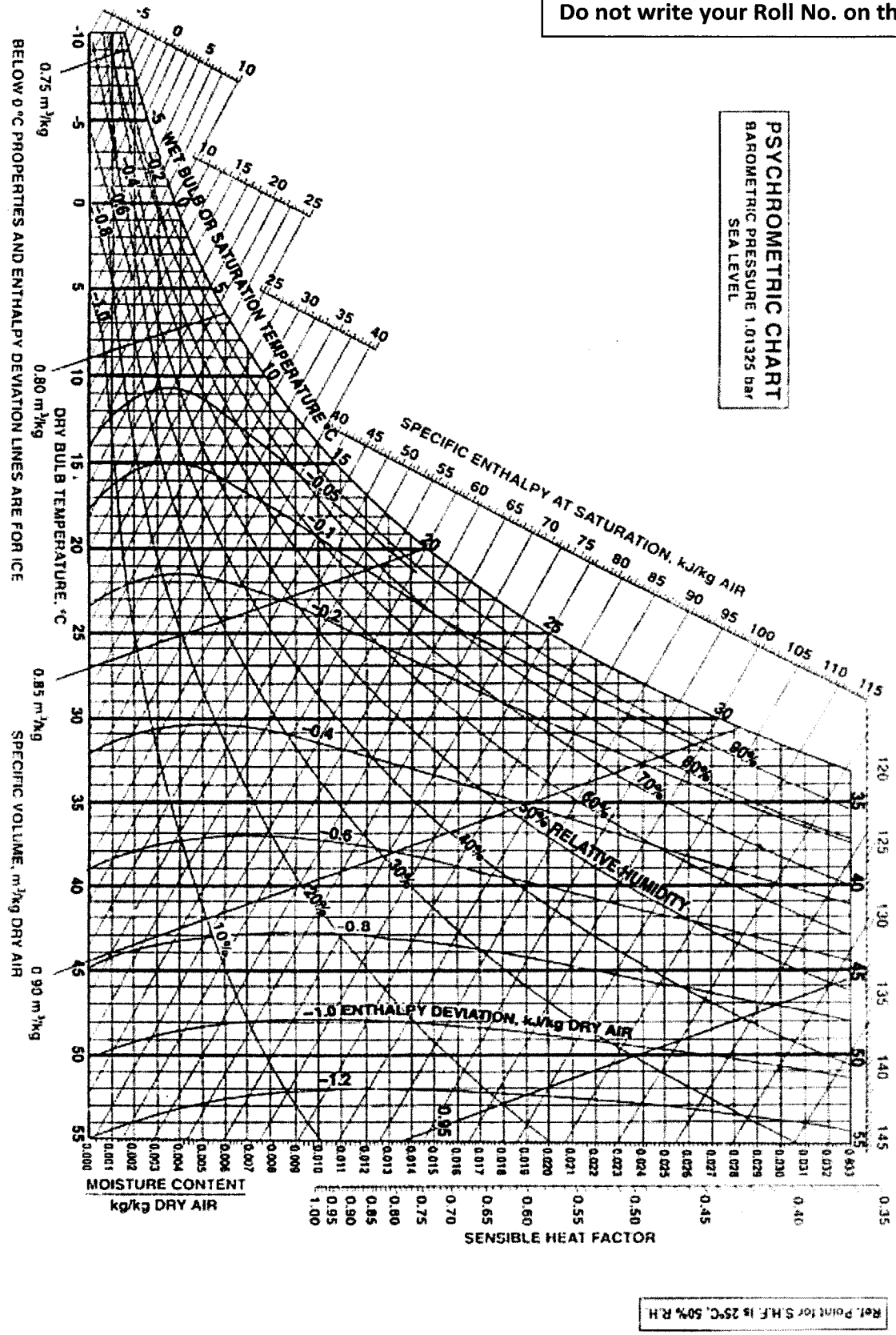

SECTION B

Q5. (a) Reciprocating pump gives fluctuating output and you want uniform or near uniform output from it. Suggest possible solutions or modifications with justifications and illustrations. *12*

(b) Draw an equivalent thermal-circuit diagram of a liquid flat plate collector with two glass covers considering the thermal resistance of glass covers. Neglect thermal resistance from sides. *12*

(c) What are the different types of stresses induced in steam turbine blades ? How are these computed and designed to safely bear them ? *12*

(d) What are regenerative fuel cells ? Briefly describe its working with a properly labelled diagram. *4+8*

(e) A gas turbine power plant operating on an ideal Brayton cycle takes in air at the initial conditions of 5°C and 1·03 bar. The pressure ratio is 7 and the maximum temperature is 816°C. Determine the work ratio and the mass flow rate of air for a net output of 3750 kW. *12*

For air C_p = 1·005 kJ/kg K and γ = 1·4.

Q6. (a) An axial compressor stage has the following data :

Temperature and pressure at entry = 300 K, 1·0 bar

Degree of reaction = 50%

Mean blade ring diameter = 36 cm

Rotational speed = 18000 rpm

Blade height at entry = 6 cm

Air angles at rotor and stator exit = 25°

Axial velocity = 180 m/s

Work done factor = 0·88

Stage efficiency = 85%

Mechanical efficiency = 96·7%

Determine : *20*

(i) Air angles at rotor and stator entry

(ii) Mass flow rate of air

(iii) Power required to drive the compressor

(iv) Loading coefficient

(v) Pressure ratio developed by the stage

(b) A centrifugal pump with backward curved vanes is running at 1200 rpm against a head of 35 m. The discharge through the pump is 0·28 m^3/s. If the blade angle at outlet is 30°, flow velocity at outlet is 4 m/s and hydraulic or manometric efficiency is 0·85, determine diameter and width of impeller at outlet. Draw velocity triangles. *20*

(c) (i) How is biogas production related to sustainable waste management ?

(ii) What is meant by biogas enrichment ?

(iii) Explain the working of a power generation set-up using municipal organic waste. *4+6+10*

Q7. (a) Parabolic trough collector based solar thermal power plants with thermal storage are becoming popular as they can generate power even during off-sunshine hours. Explain the working of such a plant with neat sketch. Also explain the basic thermodynamic cycle, on which such plants operate, using T-s plot. *20*

(b) A Kaplan turbine generates 12 MW of shaft power under 20 m head. If inlet guide vane angle is 30° and diameters of runner and hub are taken to be 6 m and 4 m respectively, determine (a) runner vane angles (inlet and outlet), (b) guide vane angle at outlet, and (c) speed of runner. The absolute velocity at the outlet should be kept minimum. Assume hydraulic efficiency as 80% and overall efficiency as 75%. Draw velocity triangles. *20*

(c) (i) If the circulation ratio is 12·5, find the dryness fraction at the top of a riser tube of a boiler. *3*

(ii) Feedwater enters the economizer at 170°C and leaves at 336·75°C whereas flue gas enters the economizer at 815°C and leaves at 450°C. If overall heat transfer coefficient is 70 W/m^2 K and heat transfer through economizer is 511134 kW, determine the outside surface area. *7*

(iii) A surface condenser receives 250 t/h of steam at 40°C with 12% moisture. The cooling water enters at 32°C and leaves at 38°C. The pressure inside the condenser is found to be 0·078 bar. The velocity of circulating water is 1·8 m/s. The condenser tubes are of 25·4 mm outer diameter and 1·25 mm thickness. Taking overall heat transfer coefficient as 2600 W/m^2 K, determine the rate of flow of cooling water, the rate of air leakage into the condenser shell, the length of tubes and number of tubes. At 40°C, h_{fg} = 2407 kJ/kg, p_{sat} = 0·07375 bar, v_f = 0·001008 m^3/kg and v_{fg} = 19·544 m^3/kg. *10*

Q8. (a) Wind is blowing at a speed of 12 m/s. It enters a turbine wheel at standard atmospheric pressure and 15°C. The turbine wheel has a cross-sectional area of 90 m^2. Determine the power of the incoming wind, theoretical maximum possible power available according to Betz criterion and a reasonably attainable turbine power in kW assuming 40% efficiency of the turbine. Find out the torque if the turbine wheel rotates at 30 RPM. Also determine the axial thrust if the turbine were operating at maximum efficiency. *20*

(b) The following data refers to a two-row velocity compounded impulse wheel which forms the first stage of a combination turbine :

Steam velocity at nozzle outlet	: 630 m/s
Mean blade velocity	: 125 m/s
Nozzle angle	: 16°
Outlet angle, first row of moving blades	: 18°
Outlet angle, fixed guide blades	: 22°
Outlet angle, second row of moving blades	: 36°
Steam flow rate	: 2·6 kg/s

The ratio of the relative velocity at outlet to that at inlet is 0·84 for all the blades. Calculate :

(i) The velocity of whirl

(ii) The tangential thrust on the blades

(iii) The axial thrust on the blades

(iv) The power developed

(v) The blade efficiency *20*

(c) A Francis turbine is running at 500 rpm under a head of 190 m. The blade angle at inlet is 50° and guide vane angle at inlet is 20°. If the peripheral speed of runner at inlet is 35 m/s and discharge is 9 m^3/s, determine (i) power developed by the runner, (ii) diameter and width of the runner at inlet, and (iii) hydraulic efficiency of the turbine.
Draw velocity triangle at inlet. *20*

MECHANICAL ENGINEERING

Paper II

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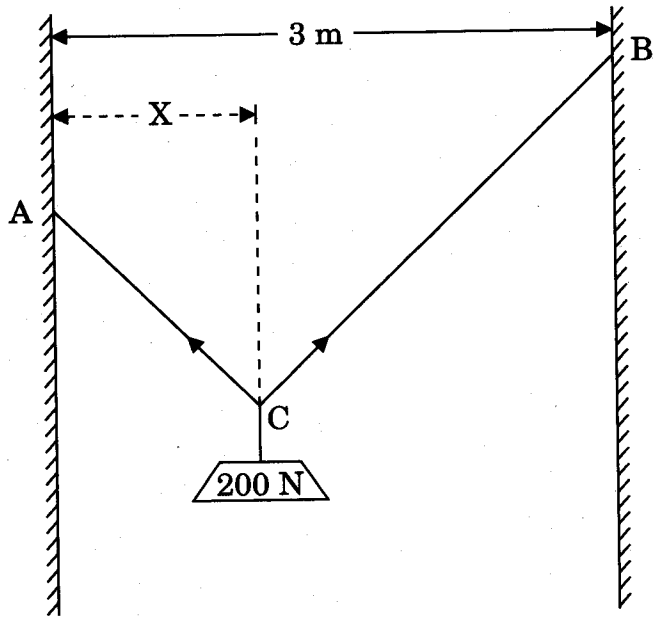
SECTION A

Q1. (a) A cord ACB 5 m long is attached at points A and B to two vertical walls 3 m apart as shown in the figure. A pulley C of negligible radius carries a suspended load of 200 N and is free to roll without friction along the cord. Determine the position of equilibrium as defined by the distance X, that the pulley will assume and also the tensile force in the cord. *12*



(b) For a beam of hollow rectangular section of outer geometry of b × d and the inner geometry of $b_1 \times d_1$, compute the area moment of inertia about its axis passing through its C.G. Also compute the area moment of inertia about a line passing through the base and also compute the same about a line passing through the vertical side. Compare the results and offer your remarks if the ratio of b : d = 1 : 2 units and in the same scaling the ratio of $b_1 : d_1$ = 0·8 : 1·6 units. *12*

(c) (i) Explain about a double slider crank chain and its inversions. *8*

(ii) The distance between two parallel shafts is 18 mm and they are connected by an Oldham's coupling. The driving shaft revolves at 160 rpm. What will be the maximum speed of sliding of the tongue of the intermediate piece along the groove ? *4*

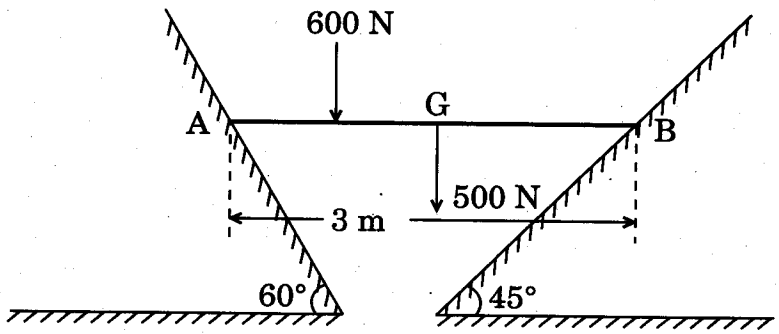
(d) A rotor has a mass of 10 kg and is mounted midway on a 20 mm diameter horizontal shaft supported at the ends by two bearings. The bearings are 1 m apart. The shaft rotates at 2000 rpm. If the centre of the mass of the rotor is 0·11 mm away from the geometric centre of the rotor due to a certain manufacturing defect, find the amplitude of the steady-state vibration. Take E = 200 GN/m^2. Assume the shaft to be simply supported. *12*

(e) The non-zero stress components at the critical point in the hub of a flywheel where yield is initiated are σ_{XX} = 100 MPa, σ_{YY} = – 20 MPa and τ_{XY} = 50 MPa. The flywheel material has a yield strength S_y = 300 MPa.

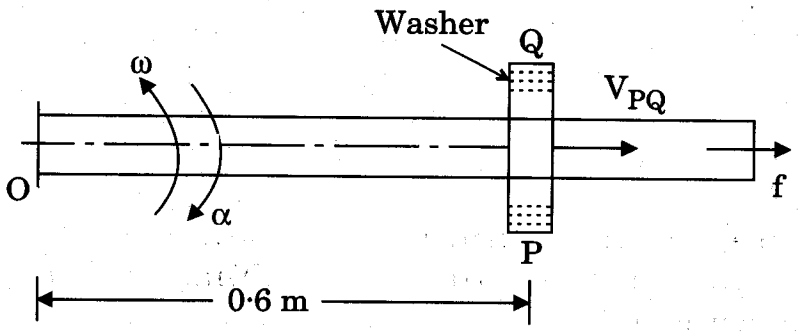
(i) Determine the principal stresses and maximum shear stress. Also show them in the Mohr's circle of stress.

(ii) Compare the factor of safety with Tresca's maximum shear stress theory and von Mises failure theory. *12*

Q2. (a) A horizontal bar AB of length 3 m and weighing 500 N is laying in a trough as shown in the figure below. Find how close to the end A and B can a load of 600 N be placed safely, if coefficient of friction between the bar and support is 0·2. *20*



(b) In the figure shown below, the washer is sliding outward on the rod with a velocity of 1·2 m/s when its distance from point 'O' is 0·6 m. Its velocity along the rod is increasing at the rate of 0·9 m/s^2. The angular velocity of the rod is 5 rad/s counter-clockwise and its angular acceleration is 10 rad/s^2 clockwise. Determine the absolute acceleration of a point in the washer. *20*

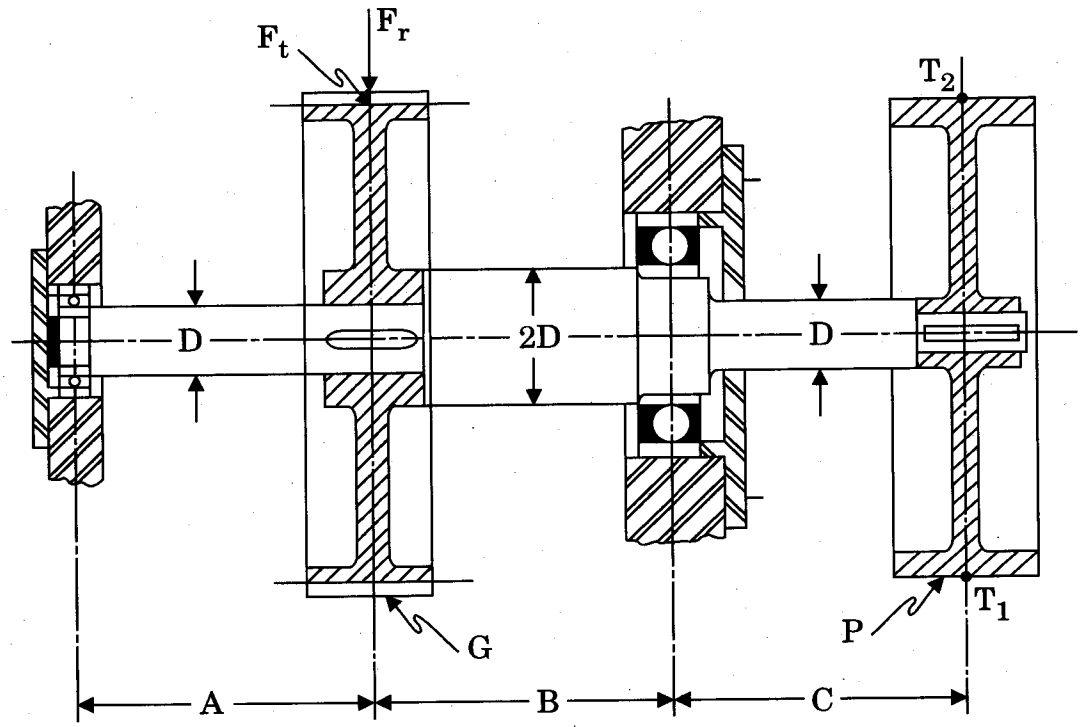


(c) The shaft shown in the figure is to be designed from the standpoint of strength. Power is supplied to the pulley P by means of a flat belt and power is taken from the shaft through spur gear G. The shaft is supported by two deep groove ball bearings.

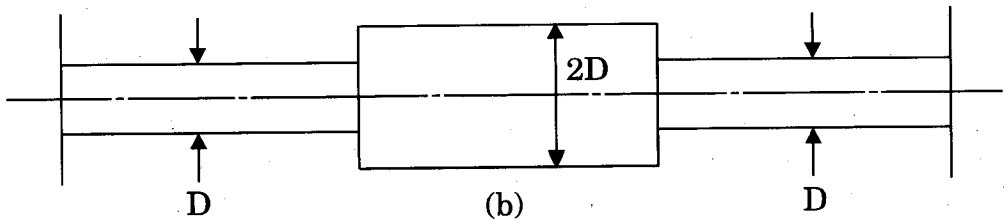
The following information has been established :

Power = 7·5 kW (steady load conditions), speed of shaft = 1000 rev/min, diameter of pulley = 250 mm, pitch diameter of the gear = 250 mm, weight of the pulley = 100 N, weight of the gear = 100 N. Ratio of belt tensions T_1/T_2 = 2·5, Gear pressure angle = 20°. Dimensions A = B = C = 150 mm in the figure. The belt forces are perpendicular to the plane of the paper, with $T_1 > T_2$ and the tangential force F_t on the gear is also perpendicular to the plane of the gear.

Shaft is to be machined from a hot rolled steel with S_{ut} = 590 MN/m^2 and S_{yt} = 380 MN/m^2. According to the ASME code, use allowable shear stress as minimum of either 0·18 S_{ut} or 0·30 S_{yt}. For steady load use k_b = 1·5 and k_t = 1·0. *20*



(a)



(b)

Q3. (a) A cantilever beam of length 'L' carries the loading as below :

(i) Carrying a uniformly distributed load of 'w' per unit run over the whole length.

(ii) Carrying a distributed load when intensity varies from zero at the free end to 'w' per unit run at the fixed end.

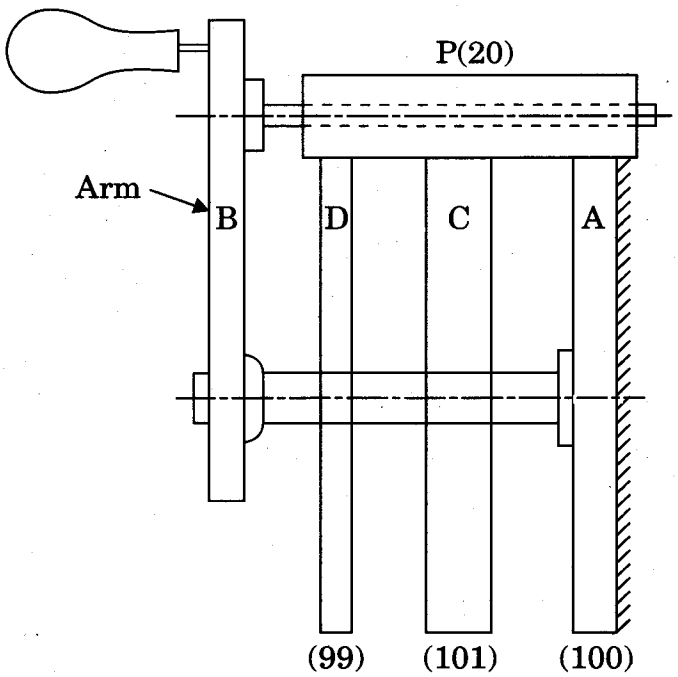
(iii) Carrying a distributed load whose intensity varies from zero at the fixed end to 'w' per unit run at the free end.

Calculate the maximum displacement and the maximum stress for each loading case and offer your remarks on the result. *20*

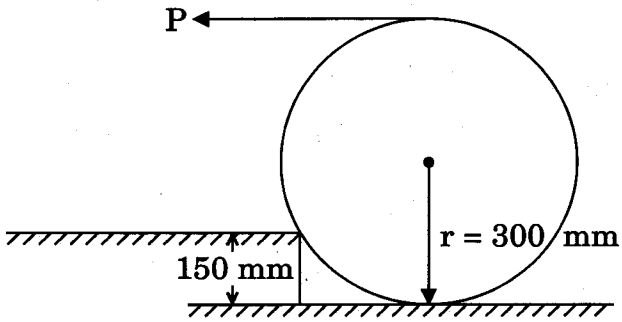
(b) (i) Define the terms Interference and Undercutting in the mating of a pair of teeth while transmitting the power and mention how we can avoid the same.

Two 20° involute spur gears have a module of 10 mm. The addendum is one module. The larger gear has 50 teeth and the pinion 13 teeth. Does the interference occur and if it occurs, how can we eliminate the same ? *10*

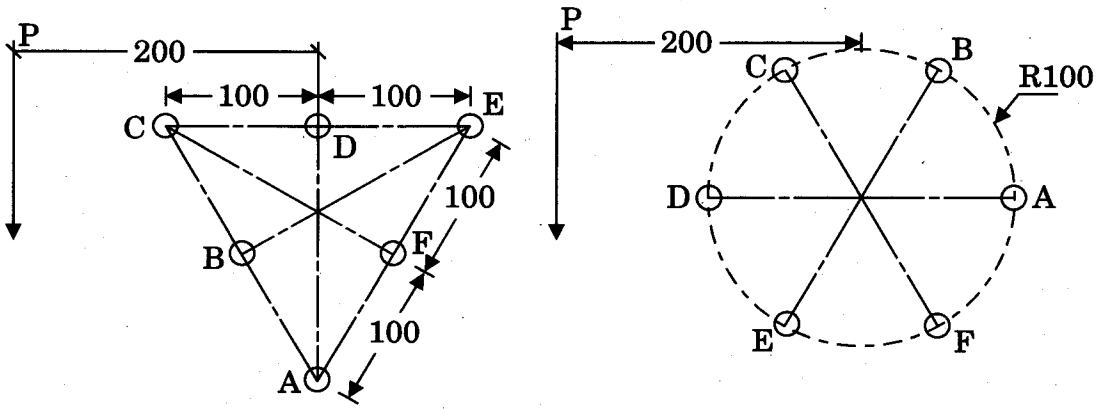
(ii) The figure below shows an epicyclic gear train known as Ferguson's paradox. Gear A is fixed to the frame and is therefore stationary. The arm B and gear C and D are free to rotate on the shaft. Gears A, C and D have 100, 101 and 99 teeth respectively. Planet gear P has 20 teeth. Pitch circle diameters of all are the same so that the planet gear P meshes with all of them. Determine the revolutions of gears C and D for one revolution of the arm B. *10*



(c) A roller of radius r = 300 mm and weight 2000 N is to be pulled over a curb of height 150 mm by a horizontal force P applied at the end of a string wound tightly around the circumference of the roller. Find the magnitude of P required to start the roller moving over the curb. What is the least pull P through the centre of the wheel to just turn the roller over the curb ? *20*



Q4. (a) A bracket is to be attached to a wall with the help of six rivets. The different arrangements in which the bracket can be attached to the wall are shown in the figure. The maximum allowable stress in shear is 60 N/mm^2. Determine the way in which the rivets should be arranged so that the design is economical. The bracket is required to support a load of 60 kN with an eccentricity of 200 mm. Determine the diameter of rivets for the two arrangements. *20*

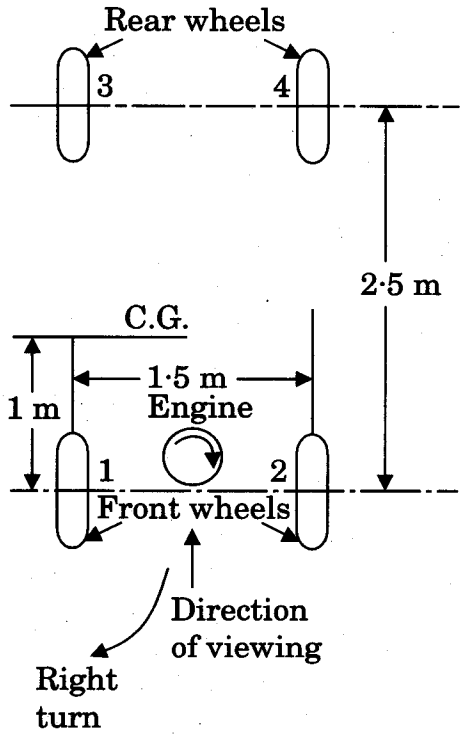


(a) Triangular Arrangement (b) Circular Arrangement

All dimensions are in mm.

(b) Draw the SFD and BMD of a simply supported beam with equal overhangs of length "a" carrying a uniformly distributed load of 'w' per unit run over the whole length 'l'. Show the BMD when a = $\frac{l}{2}$, a < $\frac{l}{2}$ and a > $\frac{l}{2}$. Offer your comments on the results. *20*

(c) A car is of total mass 200 kg. It has a wheel base equal to 2·5 m and track width equal to 1·5 m. The C.G. lies at 500 mm above ground level and 1·5 m from the rear axle. The effective diameter of each wheel is 800 mm and moment of inertia of each wheel is 1·0 kg m^2. The rear axle ratio (gear ratio) is 4. The equivalent mass of engine rotating parts is 140 kg with radius of gyration of 150 mm. The spin axis of the rotating engine parts is perpendicular to the spin axis of wheels. The engine parts are rotating in clockwise direction when viewed from the front. Determine the reaction at each wheel if the car takes a right turn of 100 m radius at 90 km/hour speed. *20*



SECTION B

Q5. (a) Prove that the atomic packing factors for BCC and FCC crystal structures are 0·68 and 0·74 respectively. *12*

(b) Enlist various wear mechanisms and explain the term Wear and Debris Analysis. *12*

(c) A work sampling study was conducted to establish the standard time for an operation. The observations of the study conducted are given below :

Total number of observations	= 160
Manual (hand controlled work)	= 14
Machine controlled work	= 106
Machine idle time	= 40
Average performance rating	= 80%
No. of parts produced	= 36
Allowance for personal needs and fatigue	= 10%
Study conducted for 3 days	
Available working hours/day	= 8 hours

Calculate the standard time per piece. *12*

(d) A cylindrical riser must be designed for a sand-casting mould. The casting itself is a steel rectangular plate with dimensions 3·75 cm × 6·25 cm × 1·0 cm. Previous observations have indicated that the total solidification time (T_{TS}) for this casting = 1·6 min. The cylinder for the riser will have a diameter-to-height ratio = 1·0. Determine the dimensions of the riser so that its T_{TS} = 2·0 min. Assume the value of n = 2, for mould constant. *12*

(e) For a 4-DOF, RPPR manipulator, the joint-link transformation matrices with joint variables θ_1, d_2, d_3 and θ_4 are given as ${}^0T_1$, ${}^1T_2$, ${}^2T_3$ and ${}^3T_4$. Generate the Denavit-Hartenberg parameters table and the frames for the manipulator as per D-H rules. *12*

$${}^0T_1 = \begin{bmatrix} C_1 & -S_1 & 0 & 0 \\ S_1 & C_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad {}^1T_2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^2T_3 = \begin{bmatrix} 1 & 0 & 0 & 10 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad {}^3T_4 = \begin{bmatrix} C_4 & -S_4 & 0 & 0 \\ S_4 & C_4 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$C_i = \cos\theta_i$, $S_i = \sin\theta_i$.

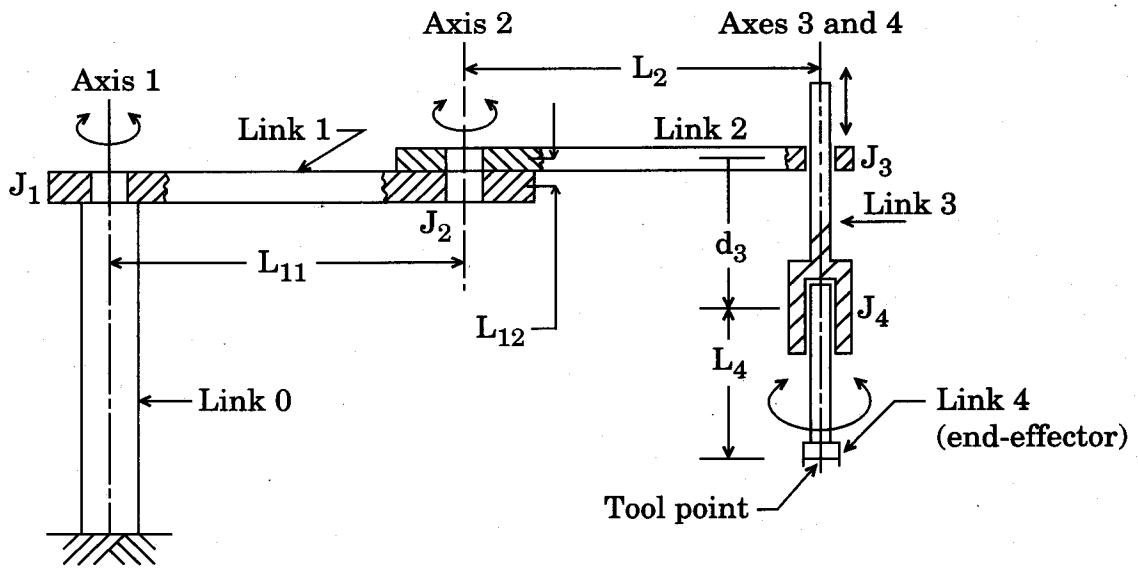
Q6. (a) Explain electrochemical considerations of corrosion for metallic materials. Discuss the principle of cathodic protection of corrosion prevention. *20*

(b) The following table gives data on normal cost and time, crash cost and time for a project. The indirect cost is ₹ 50/week.

Activity	Time (week)	Normal Cost (₹)	Crash Time	Cost (₹)
1 – 2	3	300	2	400
2 – 3	3	30	3	30
2 – 4	7	420	5	580
2 – 5	9	720	7	810
3 – 5	5	250	4	300
4 – 5	0	0	0	0
5 – 6	6	320	4	410
6 – 7	4	400	3	470
6 – 8	13	780	10	900
7 – 8	10	1000	9	1200

Draw the network diagram and label it. Identify critical path and find out normal project duration and corresponding cost. Crash the relevant activities systematically and determine the optimum project duration and cost. Determine the minimum project duration and corresponding cost. *20*

(c) Obtain the direct kinematics model of the given 4 DOF SCARA robot by developing D-H frames, D-H parameters table and individual transformation matrices. *20*



$^{i-1}T_i =$

$C\theta_i$	$-S\theta_i C\alpha_i$	$S\theta_i S\alpha_i$	$a_i C\theta_i$
$S\theta_i$	$C\theta_i C\alpha_i$	$-C\theta_i S\alpha_i$	$a_i S\theta_i$
0	$S\alpha_i$	$C\alpha_i$	d_i
0	0	0	1

Q7. (a) In an orthogonal turning operation of a mild steel bar of 60 mm diameter, cutting speed was 30 m/minute, rake angle of tool 30°, feed rate 0·10 mm/revolution, tangential force 3000 N, feed force 1300 N, length of continuous chip in one revolution 100 mm. Calculate coefficient of friction, shear plane angle, velocity of chip along tool face and chip thickness. *20*

(b) Determine the most economical order quantity when annual usage is 8000 parts. Unit commodity cost is ₹ 60 and the cost of placing an order is ₹ 150 and the annual inventory carrying cost is 30% of the average inventory. Also find out the most economical order quantity for the variable price schedule given below : *20*

Lot Size	Unit Price
1 – 200	₹ 62
201 – 500	₹ 60
501 and above	₹ 56

(c) What are nanomaterials ? Cite examples of the special properties of nanomaterials. Discuss the salient features of nanomaterials characterization tools. *20*

Q8. (a) Prepare the forward kinematic model for a 3-link planar arm with link lengths l_1, l_2 and l_3 respectively by developing *20*

(i) Respective coordinate frames as per D-H rules,

(ii) D-H parameters table,

(iii) Individual transformation matrices, ${}^{i-1}T_i$, and

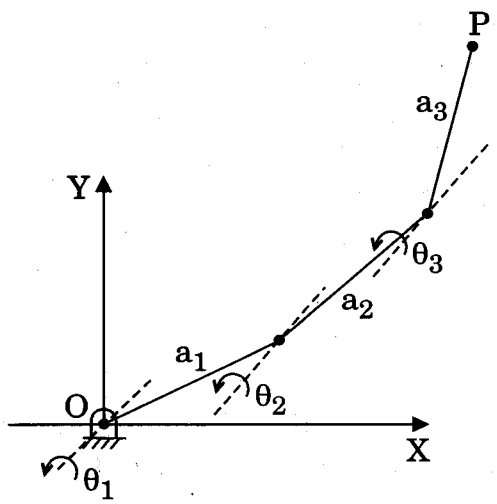
(iv) The transformation matrix of the last frame with reference to the base frame.

(v) Also draw the orientation and position of the last frame with reference to the base frame, if link lengths are

$a_1 = a_2 = a_3 = 10$ units, $\theta_1 = 0°$, $\theta_2 = 45°$ and $\theta_3 = 45°$.

Given that ${}^{i-1}T_i$ matrix form is as following.

Note : angles are measured in counter-clockwise direction.



$${}^{i-1}T_i = \begin{bmatrix} C\theta_i & -S\theta_i C\alpha_i & S\theta_i S\alpha_i & a_i C\theta_i \\ S\theta_i & C\theta_i C\alpha_i & -C\theta_i S\alpha_i & a_i S\theta_i \\ 0 & S\alpha_i & C\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(b) The following data is available for a machine in a manufacturing unit.

Number of hours worked per day	8
Working days per month	25
Number of operators	1

Standard time per unit of production

Machine time	22 min
Operator time	08 min
Total time/unit	30 min

(i) If plant is operated at 75% efficiency, and the operator is working at 100% efficiency, what is the output per month ?

(ii) It the machine productivity is increased by 10% over the existing level, what will be the output per month ?

(iii) If the operator efficiency is reduced by 20% over the existing level, what will be the output per month ? *20*

(c) Explain the methods of numerical evaluation of surface texture. Compare their merits and demerits. Describe the construction and working of a Talysurf surface roughness tester. *20*