MECHANICAL ENGINEERING

Paper I

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

INSTRUCTIONS

Please read each of the following instructions carefully before attempting the 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 from each Section.

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

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 QCA Booklet must be clearly struck off.

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

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

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

Answers must be written in ENGLISH only.

SECTION—A

1. (a) A refrigerator machine uses R-12 as the working fluid. The temperature of R-12 in the evaporator coil is –5 °C, and the gas leaves the compressor as dry saturated at a temperature of 40 °C. The mean specific heat of liquid R-12 between the above temperatures is 0.963 kJ/kg K. The enthalpy of evaporation at 40 °C is 203.2 kJ/kg. Neglecting losses, find the COP. 12

(b) Compare the knocking phenomena in SI and CI engines. Explain clearly the factors which tend to prevent knock in SI engines in fact promote knock in CI engines. 12

(c) A laboratory wind tunnel has a test section that is 305 mm square. Boundary layer velocity profiles are measured at two cross-sections and displacement thicknesses are evaluated from the measured profiles. At section 1, where the free stream speed is u_1 = 26 m/s, the displacement thickness is δ_1^* =1.5 mm. At section 2, the displacement thickness is δ_2^* =2.1 mm. Calculate the change in static pressure between sections 1 and 2 as a fraction of the free stream dynamic pressure at section 1. 12

(d) A drying oven consists of a long semicircular duct of diameter D = 1 m as shown in Fig. 1 below. Materials are to be dried over the base of the oven while the wall is maintained at 1200 K. What is the drying rate per unit length of the oven if a water-coated layer of material is maintained at 325 K during the drying process? Blackbody behavior may be assumed for the water surface and the oven wall. 12

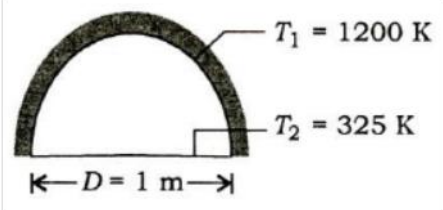


Fig. 1

(e) Explain the desirable properties of refrigerants. List all the possible alternative refrigerants to CFCs and HCFCs. 12

2. (a) In aircraft refrigerating unit using air cycle, 50 kg/min of air at 180 cm Hg gauge and 205 °C are bled off the air compressor serving the jet engine of an airplane. The bled air is passed through a heat exchanger leaving at 175 cm Hg gauge and 75 °C. At this point, it is expanded through a small cooling turbine to 20 cm Hg vacuum and −10 °C. The air exhausted out of the plane is at 25 °C. Assume C_p =10 kJ/kg K.

(i) Find the cooling in ton (refrigeration).

(ii) If the compressor receives air at stagnation state of 2 cm Hg gauge and 50 °C and if the small air-cooling turbine output serves the centrifugal fan for passing coolant air through the heat exchanger, determine the input power for the refrigerant plant.

(iii) What is the COP based on input power to bled off air? 20

(b) The pressure in an automobile tire depends on the temperature of the air in the tire. When the air temperature is 25 °C, the pressure gauge reads 210 kPa. If the volume of the tire is 0.65 m^3, determine the pressure rise in the tire when the air temperature in the tire rises to 50 °C. Also determine the amount of air that must be bled off to restore pressure to its original value at this temperature. Assume atmospheric pressure to be 100 kPa and R = 0.287 kj/kg K. 20

(c) The temperature distributions within a series of one-dimensional plane walls at an initial time (t = 0), at steady state (t = ∞) and at several intermediate times are as shown in Fig. 2 below (Case-A and Case-B). For each case, write the appropriate form of diffusion equation. Also write the equations for the initial condition and the boundary condition that are applied at x = 0 and x = L. If the volumetric generation occurs, it is uniform throughout the wall. The properties are constant. 20

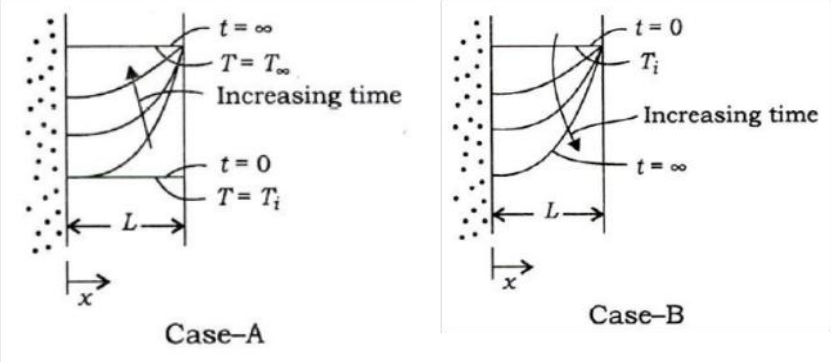


Fig. 2

3. (a) Determine the change of air-fuel ratio of an airplane engine carburetor when it takes off from sea level to a height of 5000 m. The carburetor is adjusted for 15:1 ratio at sea level, where the air temperature is 27 °C and pressure 1 bar. Assume the variation of temperature of air with altitude as $t = t_s - 0.0065h$, where h is in meter and t is in °C. The air pressure decreases with altitude as per the relation $h = 19200 \log_{10}(1/p)$, where p is in bar. Evaluate the variation of air-fuel ratio with respect to altitude in steps of 1000 m on the trend. Show the variation on a graph and discuss. 20

(b) Consider the laminar flow of a fluid layer falling down on a plane at an angle θ with the horizontal. If h is the thickness of the layer in the fully developed stage, then—

(i) show that the velocity distribution is $U = g\sin\theta(h^2 - y^2)/2\nu$, where ν is the kinematic viscosity (the x-axis points along the free surface and the y-axis points towards the plane);

(ii) develop the expression for volume flow rate per unit width;

(iii) develop the expression for frictional stress on the wall. 20

(c) Derive the Euler's equation for turbo-machines and show that for single-stage axial impulse turbine, work done can be represented as $W = \frac{1}{2}\left(V_1^2 - V_2^2\right)$, where V_1 and V_2 are absolute velocities at inlet and exit of rotor blades. 20

4. (a) Explain the working of electrostatic precipitator and discuss variation of its collection efficiency with operating parameters like collector area, migration velocity and mass flow rate. 20

(b) What are the three different types of fuel cell reactions? Give the hydrogen-oxygen, carbon-oxygen and methane-oxygen fuel cell reactions. 20

(c) Steam enters the condenser of a steam power plant at 20 kPa and a quality of 95% with a mass flow rate of 20000 kg/h. It is circulating the water through the tubes within the condenser. To prevent thermal pollution, the river is not allowed to experience a temperature rise above 10 °C. If the steam is to leave the condenser as saturated liquid at 20 kPa, determine the mass flow rate of the cooling water required.

Data from steam table: At 20 kPa, h_f = 251.4 kj/kg; h_{fg} = 2358.3 kJ/kg; Specific heat of water = 4.18 kJ/kg °C. 20

SECTION—B

5. (a) A 30 kg iron block and a 20 kg copper block both initially at 80 °C are dropped into a large lake at 20 °C. Thermal equilibrium is established after a while as a result of heat transfer between the blocks and the lake water. Determine the total entropy change for this process. For copper and iron, specific heats are respectively 0.386 kJ/kg K and 0.46 kJ/kg K. 12

(b) The wind speed V_1 at a location is 4.472 m/s, the speed at turbine rotor is 60% of this value and the speed at the exit is 30% of V_1, The rotor diameter is 9 m, density = 1.293 kg/m^3. Calculate (*i*) the power available in the undisturbed wind at the turbine rotor, (*ii*) the power in the wind at outlet, (*iii*) the power developed by the turbine and (*iv*) the coefficient of performance. 12

(c) It has been seen that long blades are twisted along the height. With proper figure, explain reasons for twisting. 12

(d) Show all the heat losses taking place from flat plate solar collector with the help of a sketch. Using energy balance, develop performance equation and explain graphically also. 12

(e) Briefly discuss rubbing, pumping and auxiliary frictional losses in IC engines. 12

6. (a) Two identical vehicles are fitted with engines having the following specifications:

Engine 1 : Naturally aspirated, swept volume 3.6 liters, brake mean effective pressure 9 bar, speed 5000 r.p.m,, compression ratio 8, efficiency ratio 0.5, mechanical efficiency 90% and mass 250 kg

Engine 2 : Swept volume 3.6 liters, brake mean effective pressure 12 bar, speed 5000 r.p.m., compression ratio 6, efficiency ratio 0-5, mechanical efficiency 90% and mass 260 kg

Identify the engines. If both the engines are supplied with just enough fuel for test run, determine the duration of the test run so that the specific mass is same for both the arrangements. Take the calorific value of the fuel as 43 MJ/kg. 20

(b) Steam at 175 bar and 550 °C expands to 0.1 bar in a steam turbine. The blade peripheral velocity is 250 m/s. The nozzle angles for impulse and reaction stages are 15° and 20° respectively. If all the stages are operated close to

maximum efficiency, determine the number of stages for the following arrangements:

(Take saturated water entropy, enthalpy, entropy of evaporation and enthalpy of evaporation at 0.1 bar as 0.6493, 191.8, 7.5009 and 2392.8 respectively.)

(i) All reaction stages

(ii) First 2-row velocity compounding followed by 50% reaction stages 20

(c) A solar flux of 800 W/m^2 is incident on a flat plate solar collector used to heat water. The area of the collector is 4 m^2 and 90% of the solar radiation passes through the cover glass and is absorbed by the absorber plate as shown in Fig. 3. The remaining 10% is reflected away from the collector. Water flows through the tube passages on the back side of the absorber plate and is heated from an inlet temperature, T_i to an outlet temperature, T_0. The cover glass operating at a temperature of 30 °C has an emissivity of 0.94 and experiences radiation exchange with the sky at –10 °C. The convection coefficient between the cover glass and the ambient air at 25 °C is 10 W/m^2 K.

(i) Obtain an expression for the rate at which useful heat is collected per unit area of the collector, q_u'' by performing an overall energy balance on the collector.

(ii) Determine the value of q_u''.

(iii) Calculate the temperature rise of the water, $T_0 - T_i$, if the flow rate is 0.01 kg/s. Assume the specific heat of water to be 4179 J/kg K.

(iv) Calculate the collector efficiency. Note that the collector efficiency is defined as the ratio of the useful heat collected to the rate at which solar energy is incident on the collector.

Data: $\sigma = 5.67 \times 10^{-8}$ W/m^2 K^4.

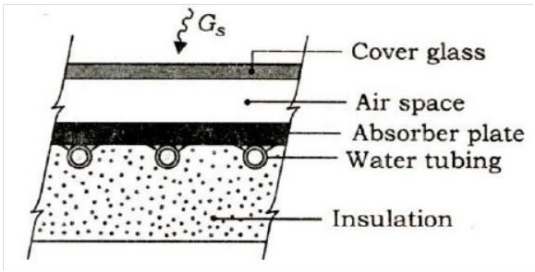


Fig. 3

7. (a) Air at 12 °C DBT and 70% RH is to be heated and dehumidified to 36.5 °C DBT and 21 °C WBT. The air is preheated sensibly before passing to the air washer in which water is recirculated. The RH of the air coming out of the air washer is 70%. This air is again reheated sensibly to obtain the final derived condition. Determine the (*i*) temperature to which the air should be preheated, (*ii*) total heating required, (*iii*) make-up water required in the air washer and (*iv*) humidifying efficiency of the air washer. 20

(b) The pump characteristic of a centrifugal pump with impeller diameter, D = 200 mm operating at 1170 r.p.m. is given by

$$H_1 = 7.6 - 1.95 \times 10^{-4}\, Q_1^2$$

where H is in m and Q is in m^3/h. For this pump operating at this speed (N_1 = 1170 r.p.m.), the best efficiency point corresponds to flow rate of 68 m^3/h and head equal to 6.7 m. You need to develop an equation at N = 1750 r.p.m. for the same pump expressed as

$$H_2 = H_{o2} - A_2 Q_2^2$$

Find out the value of H_{o2} and A_2. 20

(c) A tidal project has an installed capacity of 2176 MW in 64 units, each of 34 MW

rated output. The head at rated output is 5.52 m. The embankment is 6.4 km long. Assume 93% efficiency for both turbine and generator. The generation works for 5 hours twice a day. Calculate (*i*) the quantity of water flowing through each turbine and the total flow out of the tidal basin, (*ii*) the surface area of the reservoir behind the embankment and the wash and (*iii*) the energy produced in TWh per year. 20

8. (a) A thermoelectric refrigerator is powered by a car battery and has a COP of 0.1. The refrigerator cools a 0.35×10^{-3} m^3 canned drink from 20 °C to 4 °C in 30 minutes. The properties of canned drink are same as that of water at room temperature, i.e., $\rho = 1000$ kg/m^3 and $C = 4.18$ kJ/kg K. Neglecting the heat transfer through the walls of the refrigerator, determine the average electric power consumed by the thermoelectric refrigerator. 20

(b) Discuss the effect of regeneration in gas turbine cycle. Draw the cycle efficiency vs. pressure ratio curve and explain why efficiency drops with increase in pressure ratio. 20

(c) A thermal energy storage unit consists of a large rectangular channel which is well insulated on its outer surface and encloses alternating layers of the storage material and the flow passage as given below in Fig. 4. Each layer of the storage material is an aluminum slab of width 0.05 m which is at an initial temperature of 25 °C. Consider conditions for which the storage unit is charged by passing a hot gas through the passages with the gas temperature and the convection coefficient assumed to have constant values of $T_\infty = 600$ °C and $h = 100$ W /m^2 K throughout the channel.

(i) How long will it take to achieve 75% of the maximum possible energy storage?

(ii) What is the temperature of aluminum at this time? 20

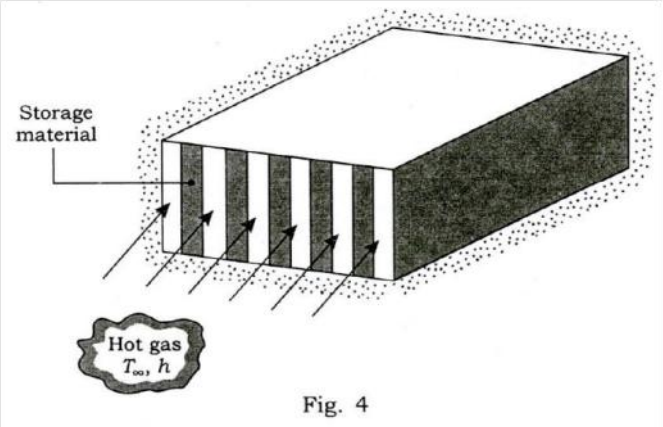


Fig. 4

MECHANICAL ENGINEERING

Paper II

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, **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.

Answers must be written in the medium authorized in the Admission Certificate which must be stated clearly on the cover of this Question-cum-Answer (QCA) Booklet in the space provided. No marks will be given for answers written in a medium other than the authorized one.

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

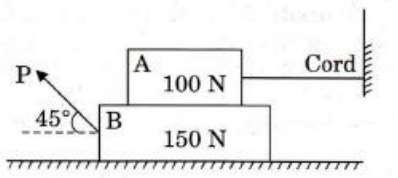
Unless otherwise mentioned, symbols and notations carry their usual standard meanings.

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

1. (a) A 100 N block A rests on a 150 N block B, which rests on a rough horizontal plane. The block A is tied with a weightless horizontal cord to a wall. A force P is applied to the block B at 45° to the horizontal as shown in the figure. If the coefficient of friction is 0.25 between the blocks and 0.3 between block B and the floor, determine the tension T in the cord and the value of the force P so that block B is at the point of sliding. 12



(b) (i) Find the maximum flexural stress developed in a steel wire 2.00 mm in diameter, if it is coiled over a drum 0.5 m in radius (it is assumed that the limit of proportionality is not exceeded due to coiling). What is the bending moment to which the wire is subjected? Take E = 200 GPa. 6

(ii) If the ratio of Young's modulus to the modulus of rigidity is 2.5 for a certain material, find its Poisson's ratio and the ratio of Young's modulus to bulk modulus. 6

(c) An aeroplane flying at 300 km/h turns towards the left and completes a quarter circle of 80 m radius. The mass of the rotary engine and the propeller of the plane is 500 kg with a radius of gyration of 300 mm. The engine speed is 2000 r.p.m. clockwise when viewed from the nose end (front end). Determine the gyroscopic couple on the aircraft and state its effect whether the nose end is raised or depressed. 12

(d) (i) Define the following terms for the governor :

- Sensitiveness
- Stability
- Isochronous

- Hunting

(ii) Draw the controlling force (F_c) vs. radius of rotation of balls (r) for spring controlled governors for the above conditions. 12

(e) A gear set consists of an 18-tooth pinion driving a 45-tooth gear. The module is 10 mm. The gears are cut using a pressure angle of 20°. In mounting the gears, the centre distance was incorrectly made 8 mm larger. Compute the new values of the pressure angle and pitch circle diameter. If the pinion transmits 20 kW and rotates at 950 r.p.m., determine the forces on the tooth for mounted gears. 12

2. (a) A beam of uniform section and length (L + 2a) is simply supported over a span L with two equal overhanging lengths 'a'. Compute the deflection at mid span due to a uniformly distributed load w/unit length when covering the length L between the supports and when covering only two overhanging lengths. EI is the flexural rigidity of the beam. 20

(b) A cam operates a roller reciprocating follower with the following data :

Minimum radius of the cam = 24 mm

Lift = 30 mm

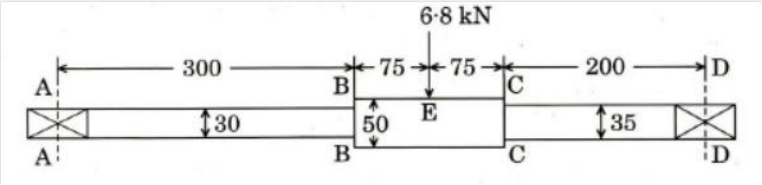
Roller diameter = 16 mm

The cam lifts the follower for 120° with SHM followed by a dwell period of 40°. Then the follower lowers down during 150° of the cam rotation with uniform acceleration and deceleration followed by a dwell period.

(i) Draw the profile of the cam.

(ii) If the cam rotates at a uniform speed of 160 r.p.m., calculate the maximum velocity and acceleration of the follower during the descent period. 20

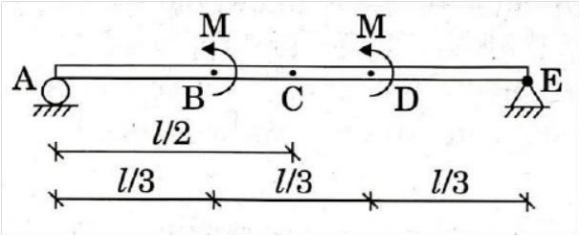
(c) A rotating shaft shown in the figure below is supported in ball bearings at A and D and loaded by a non-rotating force of 68 kN. The shaft is made of 40 C8 steel (σ_y = 360 N/mm², σ_u = 650 N/mm2). Endurance limit σ_e may be taken as 55% of σ_u. The shaft is machined. The reliability is 90% (reliability factor c_r is 0.897). Static stress concentration at BB may be taken as 1.5 and at CC 1.4. The notch sensitivity factor q may be taken as 0.95.



All dimensions are in mm

Find out the critical section and factor of safety. 20

3. (a) (i) Draw the shear force and bending moment diagram for the given simply supported beam with moment loads as shown in the figure. Show the magnitude of shear force and bending moments at the respective points of the beam, i.e., at A, B, C, D and E. 10



(ii) Determine the maximum shear stress values for the given set of principal stresses. Draw the Mohr's stress circle for each case and show the maximum shear stress on it. 10

(A) $\sigma_1 = \sigma$, $\sigma_2 = \sigma/2$, $\sigma_3 = 0$

(B) $\sigma_1 = \sigma, \sigma_2 = -\sigma, \sigma_3 = 0$
(C) $\sigma_1 = \sigma, \sigma_2 = 0, \sigma_3 = 0$
(D) $\sigma_1 = \sigma_2 = \sigma_3 = \sigma$

(b) (i) Derive the expression for minimum number of teeth on a pinion for involute rack in order to avoid interference.
(ii) A pinion of 30 involute teeth and 4 mm module drives a rack. The pressure angle is 20°. The addendum of both, the pinion and the rack is the same. What is the permissible value of the addendum to avoid interference?
15 + 5 = 20

(c) A pair of spur gears with pressure angle 20° consists of a 24-tooth pinion which rotates at 950 r.p.m. and transmits power to a 60-tooth gear. The module is 6 mm and face width is 60 mm. Both the gears are made of 45 C8 steel (σ_y = 330 N/mm^2, σ_u = 680 N/mm^2 and $\sigma_e = 0.55\ \sigma_u$). Take surface endurance limit 1500 N/mm2. Assuming overload factor as 1.8, dynamic factor as 20.5 and taking factor of safety of 2.5, determine :
(i) Beam strength
(ii) Wear strength
(iii) The rated power, the gears can transmit. 20
$E = 2.1 \times 10^5$ N/mm^2

4. (a) A steam turbine delivers 8200 kW of power at 1800 r.p.m. This power is received by a shaft coupled with the turbine. This shaft delivers this power to the other shaft through gear reduction unit at 90% efficiency. The other shaft rotates at 107 r.p.m. Determine the diameters of both the solid shafts. Take allowable shear stress as 3.45×10^8 N/m^2. Further, if these shafts are replaced by hollow shafts with internal diameters half of the outer diameter, determine the internal and external diameters of both the shafts. 20

(b) A 100 kg machine is symmetrically supported on four springs. The mass of the reciprocating parts is 25 kg which move through a vertical stroke of 100 mm with SHM.
Neglecting damping, determine the combined stiffness of the springs so that the force transmitted to the foundation is 1/20th of the impressed force. The machine crankshaft rotates at 850 r.p.m.
If under actual working conditions, the damping reduces the amplitudes of successive vibrations by 30%, find
(i) the force transmitted to the foundation at 850 r.p.m.,
(ii) the force transmitted to the foundation at resonance, and
(iii) the amplitude of the vibration at resonance. 20

(c) A ball bearing operates on a work cycle consisting of three parts — a radial load of 3500 N at 1440 r.p.m. for 30% of the cycle, a radial load of 6000 N, 750 r.p.m. for 35% of the cycle and a radial load of 2500 N at 1440 r.p.m. for the remaining cycle. The expected life of the bearing is 10,000 hours. Calculate the dynamic load carrying capacity of the bearing. 20

Section - B

5. (a) Explain briefly: Nitriding, Cyaniding, Flame Hardening and Induction Hardening. 12

(b) Classify gating designs in respect to pouring of molten metals into the mould cavity in the casting process. Give sketches of (i) simple vertical gating, and (ii) bottom gating design provisions. 12

(c) M/s TV Assembler needs 10,000 tubes per annum. The cost of one procurement is Rs. 80.00. The holding cost per tube is Rs. 3.00 per annum. The rush

purchase of tubes, if not in stock, amounts to equivalent shortage cost of Rs. 6.00 per tube per annum.

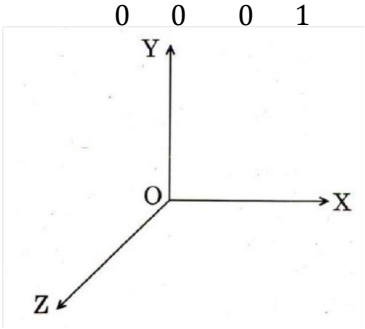
If the order is delivered instantaneously, determine how much he should order, at what interval and what will be the total cost of inventory. 12

(d) (i) List out any six inherent characteristics of a hydraulic actuator.

(ii) Explain the working of a gear pump with the help of a schematic diagram. Also detail its other properties. 12

(e) Determine the missing elements of the following frame representation, if the frame is attached to an object in space. Also show the orientation and position of the frame F with respect to OXYZ shown. 12

$$F = \begin{matrix} ? & 0 & -1 & 5 \\ ? & 0 & 0 & 3 \\ ? & -1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{matrix}$$



6. (a) (i) Explain uniform corrosion and pitting corrosion. 10

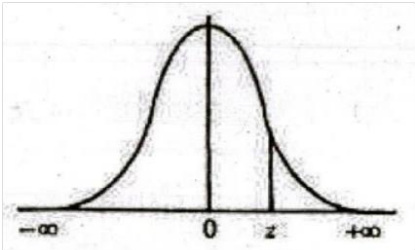
(ii) For a 79.65 wt% Fe, 0.35 wt% C, an alloy is at a temperature just below the eutectoid. Determine the fraction of total ferrite and cementite phases, the fraction of the proeutectoid ferrite and pearlite, and the fraction of the eutectoid ferrite. 10

(b) (i) The following table shows the activities of a network along with their time estimates in days:

Activity → / Estimated Time ↓	1-2	2-3	2-4	3-5	4-5	5-6
t_0	1	2	2	7	5	3
t_m	7	14	5	10	5	3
t_p	13	26	8	19	17	9

Draw the project network and find the probability of completion of the project in 40 days. 10

Normal Distribution Table



	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0	.5000	.5040	.5080	.5120	.5160	.5199	,5239	.5279	5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	5793	.5832	5871	.5910	5948	.5987	6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	6406	.6443	6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	7019	.7054	7088	.7123	7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	,7454	,7486	7517	.7549
.7	7580	.7611	.7642	.7673	.7704	7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	8051	.8078	.8106	.8133

.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	,8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	9251	.9265	,9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	9418	.9429	.9441
1.6	9452	.9463	.9474	.9484	.9495	.9505	9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	,9599	,9608	.9616	.9625	,9633
1.8	,9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	,9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	,9750	.9756	.9761	.9767
2.0	.9772	9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	,9941	.9943	.9945	.9946	.9948	.9949	.9951	9952
2.6	.9953	.9955	.9956	.9957	.9959	,9960	9961	.9962	9963	9964
2.7	,9965	.9966	.9967	.9968	.9969	,9970	.9971	.9972	.9973	.9974
2 8	.9974	.9975	9976	.9977	.9977	.9978	.9979	.9979	9980	.9981
2.9	9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	,9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	,9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	,9997	.9998

(ii) Describe with an illustrative sketch the "Ultrasonic Welding" process. *10*

(c) Answer the following : 4 +16 = 20

(i) Explain the following control strategies:

(A) Proportional Control (P)

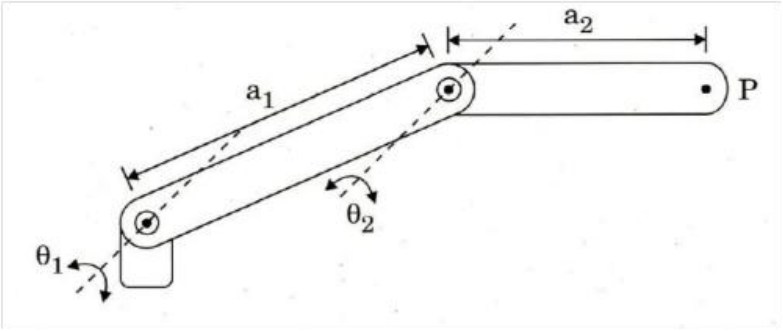
(B) Derivative Control (D)

(C) Integral Control (I)

(D) PID Control

(ii) (A) Derive the forward kinematics equations for the given figure of two degrees of freedom planar robot. Assign the coordinate frames based on D-H representations, prepare the D-H parameter table, prepare the individual transformation matrices and finally the composite transformation matrix depicting the F-K equations.

(B) If the link lengths are a_1 = 15 units and a_2 = 10 units, determine the final position and orientation of tool point (e.e.) frame for $\theta_1 = 45°$ and $\theta_2 = 45°$ (measured in counter-clockwise sense).



2 Link 2-DOF planar robot arm

7. (a) (i) Describe the stress — strain behaviour and glass transition temperature for polymers. 10

(ii) Define the term hardenability and the factors affecting it. Also name

various hardening methods. 10

(b) (i) For a deterministic inventory model assuming uniform rate of supply and fixed demand, (A) illustrate the model graphically, (B) derive the expression for optimum order quantity, (C) also derive the expression for the optimum time for ordering, and (D) derive the expression for the cost of inventory. 10

(ii) Give a schematic diagram of a piezoelectric accelerometer for shock and vibration measurement and briefly explain how it works. 10

(c) Answer the following: 5 + 15 = 20

(i) Describe in brief the following forms of memory units :

ROM, PROM, EPROM, EEPROM, RAM

(ii) Determine and compare the coordinates of a point $P(5, 3,1)^T$ attached to a moving frame F_{uvw}, which undergoes the following two sets of successive transformation:

Set A : 1. First a rotation of (–90°) about Z-axis.

2. Followed by translation of [5 –3 4] about the X, Y and Z axes respectively.

3. Finally a rotation of (–90°) about Y-axis.

Set B : 1. First a rotation of (–90°) about W-axis.

2. Followed by translation of [5 –3 4] about the U, V and W axes respectively.

3. Finally a rotation of (–90°) about V-axis.

8. (a) (i) How is the heat for electron beam welding obtained? With the help of a diagram, discuss the working of this method of welding. 10

(ii) Describe with neat sketch the method of cold drawing of a wire or a bar. 10

(b) (i) The dimensions of the mating parts according to the hole system are given below :

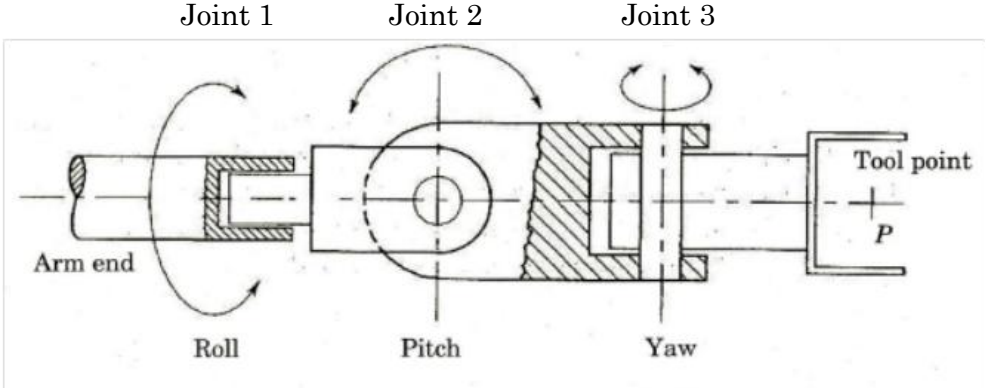
Hole	Shaft
30.0 mm	29.98 mm
30.05 mm	29.94 mm

Find the hole tolerance, shaft tolerance and allowance. 10

(ii) Illustrate and describe through a linking flow diagram, the elements of a CIM system for integrating CAD/CAM including latest communication technology to all the operational functions and information processing in manufacturing. 10

(c) Answer the following: 10 + 10 = 20

(i) Develop Forward Kinematics model for the given three degrees of freedom RPY wrist figure. Assign the frames, develop D-H parameters table, generate individual transformation matrices and overall transformation matrix. Assume $a_3 = d_3 = 0$. Determine the orientation of the last frame with reference to the {0} frame, if $\theta_1 = 0$ and $\theta_2 = \theta_3 = 90°$.



A 3-DOF freedom roll, pitch and yaw (RPY) wrist

(ii) Determine the three joint variables for a given end effector orientation

matrix TE for the RPY wrist in the figure above.

$$T_E = \begin{bmatrix} n_x & o_x & a_x & 0 \\ n_y & o_y & a_y & 0 \\ n_z & o_z & a_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$