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ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Mechanical Engineering

Test-8 : Full Syllabus Test **(Paper-II)**

Name : ....

Roll No :

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	19
Q.2	32
Q.3	–
Q.4	–
Section-B	
Q.5	41
Q.6	46
Q.7	44
Q.8	–
Total Marks Obtained	182

Signature of Evaluator .... Cross Checked by ....

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DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Section : A

Q.1 (a) A thick cylinder of 650 mm internal diameter is to be designed to sustain an internal pressure of 35 MPa. Assume an allowable stress of 180 MPa and poisson's ratio of 0.25. Determine the wall thickness by applying the below mentioned inertia of failure:

(i) Maximum principal stress theory.

(ii) Maximum shear stress theory.

[12 marks]

Given $D_i = 650mm$ $R_i = 325mm$

$R_i = 0.325m$

$P_i = 35MPa$

$\sigma_{allowable} = 180MPa$

$\mu = 0.25$

(00)

Q.1 (b) NaCl has face-centered cubic (FCC) crystal structure. Given its density is 2.18 g/cm^3, calculate the distance between two adjacent atoms in the crystal.

[12 marks]

Given FCC $r = \frac{a}{2\sqrt{2}}$

r = atomic radius a = lattice parameter/edge length

Z = n = no. of atom per unit cell = 4

$$\rho = \frac{Z(M^+ + M^-)}{A_v \times a^3}$$

$M^+ + M^- = NaCl = 22 + 34 = 56\ g/mol$

$$2.18\ g/cm^3 = \frac{4 \times 56}{6.023 \times 10^{23} \times a^3}$$

$a^3 = 1.70599 \times 10^{-22}\ cm^3$

$a = 5.54616 \times 10^{-8}\ cm$

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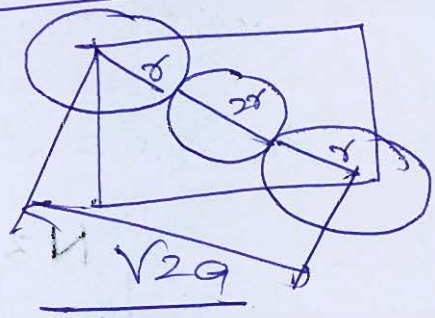
$a = 5.546 \times 10^{-10}\, m = 0.5546\, nm$

$r = \frac{a}{2\sqrt{2}}$

$r = 0.1925\, nm$

distance between two atom, $= 2r = 0.385\, nm$



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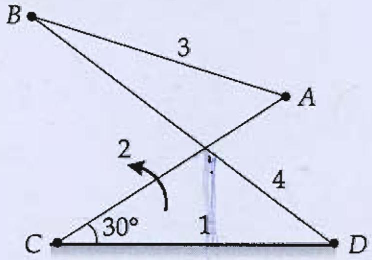
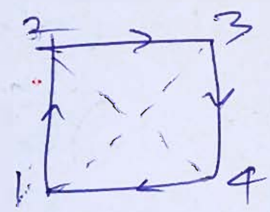
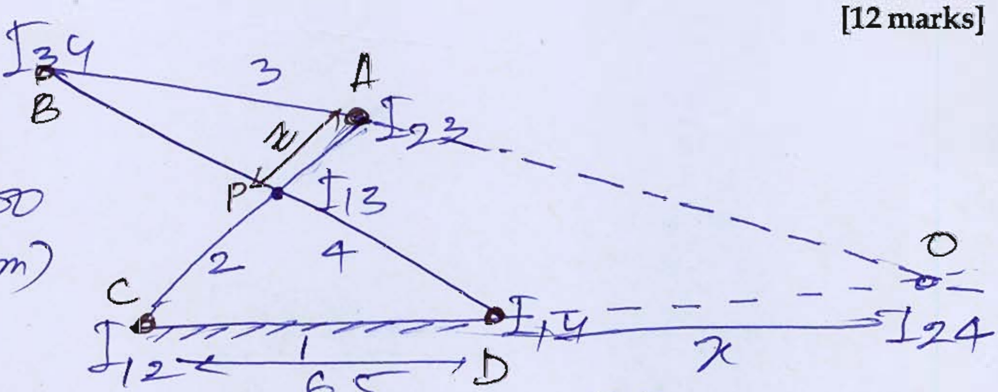
Q.1 (c) Locate all the instantaneous centers for the crossed four bar mechanism as shown in figure. The dimensions of various links are : *CD* = 65 mm, *CA* = 60 mm, *DB* = 80 mm and *AB* = 55 mm. Find the angular velocities of the links *AB* and *DB*, if the crank *CA* rotates at 100 rpm in the anticlockwise direction.





[12 marks]



$\omega_2 = 100$ rpm

$\omega_2 (I_{23} I_{21}) = \omega_3 (I_{31} I_{23})$

$100 (65) = \omega_3 (I_{31} I_{23})$

$100 (65) = \omega_3 (CA - PC)$

from triangle (PCD) $CD\cos 30° = CP$

$CD \times \sqrt{3}/2 = CP$

$CP = \frac{\sqrt{3}}{(2)} 65$

$100 \times 65 = \omega_3 \left(60 - \frac{\sqrt{3}}{(2)} \times 65\right)$

$100 \times 65 = \omega_3 (60 - 56.29)$

$N_3 = 1752.02$ rpm

~~$\omega_3 = 183.47900$ r/s~~

$AP = \left(60 \times 1 - \frac{\sqrt{3}}{2} \times 65\right) = 3.708$

from triangle APB and BDO

$\frac{BP}{PA} = \frac{BD}{DO}$ $\qquad \omega_4 = \omega_{DB}$

$\omega_2 (I_{24} I_{21}) = \omega_4 (I_{24} I_{41})$

$\left(\frac{2\pi \times 100}{60}\right)(65 + x) = \omega_4 (x)$

$\frac{BP}{3.708} = \frac{80}{x}$

X

Q.1 (d) Determine the coordinates of the centroid of the area lying between the curve $y = 5x - x^2$ and the x-axis.

[12 marks]

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Q.1 (e) A short column is of hollow circular section, the center of the inside hole being 6 mm eccentric to that of the outside. The outside diameter is 96 mm and the inside 48 mm. The line of action of the load intersects the cross-section at a point in line with the two centers. What are the limiting positions of the load for there to be no tensile stress set up?

[12 marks]

Q.2 (a) A machine of mass one tonne is acted upon by an external force of 2500 N at a frequency of 1440 rpm. To reduce the effects of vibration, an isolator of rubber having a static deflection of 2.5 mm under machine load and an estimated damping factor of 0.22 are used. Determine:

(i) The force transmitted to the foundation.

(ii) The amplitude of vibration of the machine.

(iii) The angle between the transmitted force and spring force.

[20 marks]

given $m = 1000\,kg$ $F_0 = 2500\,N$

$N = 1440$ $\omega = \frac{2\pi N}{60} = 150.796\ rad/s$

$\delta = 2.5\,mm$ $\xi = 0.22$

$$\varepsilon_T = \frac{F_T}{F_0} = \frac{\sqrt{1 + \left(\frac{2\xi\omega}{\omega_n}\right)^2}}{\sqrt{\left(1 - \left(\frac{\omega}{\omega_n}\right)^2\right)^2 + \left(\frac{2\xi\omega}{\omega_n}\right)^2}}$$

$$\omega_n = \sqrt{\frac{g}{\delta}} = \sqrt{\frac{9.81}{2.5 \times 10^{-3}}} = 62.64\ rad/s$$

$$\varepsilon_T = \frac{\sqrt{1 + \left(\frac{2 \times 0.22 \times 150.796}{62.64}\right)^2}}{\sqrt{\left(1 - \left(\frac{150.796}{62.64}\right)^2\right)^2 + \left(\frac{2 \times 0.22 \times 150.796}{62.64}\right)^2}}$$

$$\varepsilon_T = \frac{1.4567}{\sqrt{22.9649 + 1.059^2}}$$

$$\boxed{\varepsilon_T = 0.2966}$$

$$\frac{F_T}{F_0} = 0.2966 \quad F_T = 0.2966 \times 2500$$

$$\boxed{F_T = 741.57\,N}$$ Ans

$$A = \frac{F_0/k}{\sqrt{\left(1 - \left(\frac{\omega}{\omega_n}\right)^2\right)^2 + \left(\frac{2\xi\omega}{\omega_n}\right)^2}} \qquad \omega_n = \sqrt{k/m} \qquad k = (\omega_n^2 \times m)$$

$$A = \frac{2500 / 62.64^2 \times 1000}{\sqrt{\left(1 - \left(\frac{150.796}{62.64}\right)^2\right)^2 + \left(\frac{2 \times 0.22 \times 150.796}{62.66}\right)^2}}$$

$$\boxed{A = 1.2974 \times 10^{-4}\,m = 0.1297\,mm}$$ Ans

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spring force $= (k \cdot \delta) = (\omega_n^2 \times m) \times \delta$

$= 62.64^2 \times 1000 \times 2.5 \times 10^{-3}$

$F_s = 9809.424$

$F_T = 741.57$

$\tan\theta = \left(\frac{F_s}{F_T}\right)$ $\quad \theta = \tan^{-1}\left(\frac{F_s}{F_T}\right)$

$\theta = \tan^{-1}\left(\frac{~~741.57~~}{~~9809.424~~}\right)$

$\theta = \tan^{-1}\left(\frac{9809.424}{741.57}\right)$

$$\boxed{\theta = 85.67^\circ}$$ Ans

Q.2 (b) It is required to design a pair of spur gears with 20° full-depth involute teeth based on Lewis equation. The velocity factor is to be used to account for dynamic load. The pinion shaft is connected to a 10 kW, 1440 rpm motor. The starting torque of the motor is 150% of the rated torque. The speed reduction is 4:1. The pinion as well as the gear is made of plain carbon steel 40C8 ($S_{ut} = 600\ \text{N/mm}^2$). The factor of safety can be taken as 1.5. Design the gears, specify their dimensions and suggest suitable surface hardness for the gears.

Assume velocity factor, $C_V = \frac{3}{3+v}$; $\sigma_{\text{bending}} = \frac{\sigma_{ut}}{3}$; Width of tooth = 10 module.

Tooth form factor, $y = \left(0.154 - \left(\frac{0.912}{z}\right)\right)$

[20 marks]

$P = 10\ kW$ $\quad n_p = 1440\ rpm$

$C_s = 1.5$ $\quad G = 4$

$K_{FOS} = 1.5$ $\quad$ pinion gear $(S_{ut} = 600\ N/mm^2)$

$\sigma_b = S_{ut}/3$ $\quad y = 0.154 - \left(\frac{0.912}{z}\right)$

$C_v = \left(\frac{3}{3+v}\right)$. $\quad b = 10m$

(left) $v = 5\,m/s$

since pinion and gear are of same material Hence pinion is weaker than gear b/z $(\sigma_b \cdot Y)_p < (\sigma_b \cdot Y)_g$

$\text{Torque} \times \left(\frac{2\pi \times N_p}{60}\right) = P$ $\quad T \times \left(\frac{2\pi \times 1440}{60}\right) = 10 \times 1000$

$\text{Torque}\ (T) = 66.314\ Nm$

$\left(F_t \times \frac{D_p}{2} = \text{Torque}\right)$ $\quad F_t \times \left(\frac{0.066}{2}\right) = 66.31$

$v = 5\,m/s = \frac{\pi \times D_p \times 1440}{60}$

$F_t = 1999.86\ N$

$F_{dynamic} = \frac{F_t \times C_s \times f}{C_v}$ $\quad C_v = \left(\frac{3}{3+v}\right)$

$C_v = \left(\frac{3}{8}\right)$

$F_{dynamic} = \frac{1999.86 \times 1.5 \times 1.5}{(3/8)} = 12000\ N$

$F_b = (\sigma_b \cdot b \cdot Y \cdot m)$

$\left(\sigma_b = \frac{S_{ut}}{3}\right)$

$F_b = \left(\frac{600}{3}\right) \times 10m \times \left(\pi \times \left(0.154 - \frac{0.912}{Z}\right)\right) \times (m)$

((left) no. of teeth in pinion $= 18$)

$F_b = 200 \times 10m \times \pi (0.1033) \times m$

(For safe design) $F_b = F_{dynamic}$

$200 \times 10m \times \pi \times 0.1033 \times m = 12000$

$m = 4.299$

(ref) $m = 5mm$ $b = 10 \times 5 = 50\ mm$

$\sigma_b = \frac{600}{3} = 200$ $D = m \cdot Z$ $D = 5 \times 18$

$D = 90mm$

$v = \frac{\pi \times 90 \times 1440}{60 \times 1000}$ $v = 6.785\ m/s$

beam strength

$F_w = D_p \cdot b \cdot Q \cdot k$

$\frac{F_t \times D_p}{2} = 66.314$

$F_t = 1473.664\ N$

$F_{dynamic} = \frac{F_t \times C_s \times f}{C_v}$

$= \frac{1473.664 \times 1.5 \times 1.5}{(3/3+6.785)}$

$F_{dynamic} = 10814.708\ N$ $y \times \pi = Y$

$Y = 0.3245$

18

$F_s = (\sigma_b \cdot b \cdot Y \cdot m)$

$= \frac{600}{3} \times 50 \times 0.3245 \times 5$

$F_s = 16226.32606$

($F_s > F_{dynamic}$) Hence unsafe

For safe design ($10814.708 = \sigma_b \cdot b \cdot Y \cdot m$)

$10814.708 = 200 \times 10m \times 0.3245 \times m$

($m = 4.0821$) ($m = 4$) mm #

$D_p = 18 \times 4 = 72mm$ $F_t = 1842\ N$

$F_{dy} = \frac{1842 \times 1.5 \times 1.5}{3/3+}$ $v = \frac{\pi \times 72 \times 1440}{60 \times 1000}$

$v = 5.4286$

#

$D_p = 4 \times 18$

$D_p = 72mm$

$F_{dy} = 11644.1\ N$ F_b $(\sigma_b \times b \cdot Y \cdot m) = 200 \times 40 \times 0.32 \times 4$

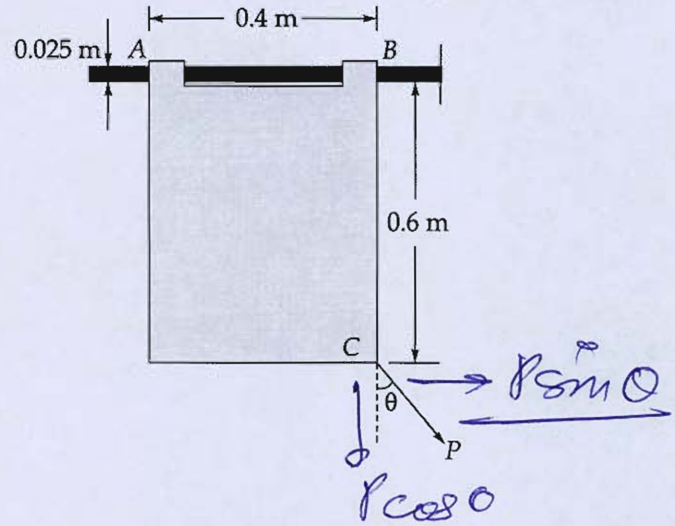
$F_{dy} > F_b$ $F_b = 10384\ N$

Hence safe

$11644.1 = D_p \cdot b \cdot Q \cdot k = 72 \times 40 \times \frac{(2 \times 4)}{5} \times k$

$BHN = 24942.9$ $k = 2.52 = 0.16 \left(\frac{BHN}{100}\right)^2$

Q.2 (c) A light metal panel is welded to two short sleeves of 0.025 m inside diameter that can slide on a fixed horizontal rod. The coefficient of friction between the sleeves and the rod are $\mu_s = 0.4$ and $\mu_k = 0.3$. A cord attached to corner C is used to move the panel along the rod. Knowing that the cord lies in the same vertical plane as the panel, determine the range of values of θ for which the panel will be in impending motion to the right. Assume that sleeves make contact with the rod at the exterior points A and B.



[20 Marks]

Q.3 (a) Draw the profile of a cam operating a knife edge follower when the axis of the follower is offset 20 mm towards right from cam axis from the following data:

(i) Follower to move outwards through 40 mm during 60° of cam rotation.

(ii) Follower to dwell for the next 45°.

(iii) Follower to return to its original position during next 90°.

(iv) Follower to dwell for the rest of the cam rotation.

The displacement of the follower is to take place with SHM during both the outward and the return strokes. The least radius of cam is 50 mm. If the cam rotates at 300 rpm, determine the maximum velocity and acceleration of the follower during the outward stroke and return stroke.

[20 marks]

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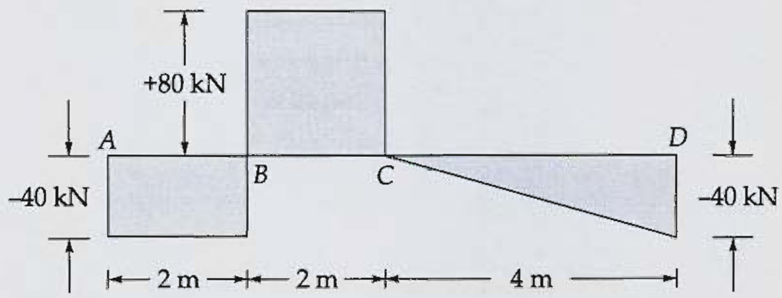
Q.3 (b) A beam *ABCD*, 8 metres long, supported over a length of 6 metres at points *B* and *D* has the shear force diagram as shown below. Determine the various loads acting on the beam and draw the bending moment diagram and find:

(i) Magnitude and position of the maximum bending moment.

(ii) Position of the point of contraflexure, if any.

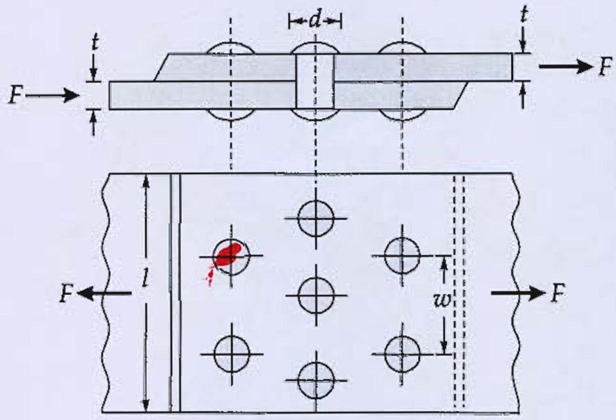


[20 marks]

Q.3 (c) In a winch, the rope supports a load W and is wound round a barrel 450 mm diameter. A differential band brake acts on a drum 800 mm diameter which is keyed to the same shaft as the barrel. The two ends of the bands are attached to pins on opposite sides of the fulcrum of the brake lever and at distance of 25 mm and 100 mm from the fulcrum. The angle of lap of the brake band is 250° and the co-efficient of friction is 0.25. What is the maximum load W which can be supported by the brake when a force of 750 N is applied to the lever at a distance of 3000 mm from the fulcrum?

[20 marks]

Q.4 (a) Two steel plates with a dimension of $l \times t$ is 180 mm × 12 mm are joined by rivets as shown in the figure. The diameter of the rivets, d is 18 mm and the pitch is w is 50 mm. The allowable tensile stress of the plate, allowable shear stress of the rivet and allowable bearing stress between the rivet and plate are 200 MPa, 150 MPa and 300 MPa respectively. Check the strength of the rivet joint if a force of 200 kN is applied. If the strength is deficient, how can the design be improved?



[20 marks]

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Q.4 (b) Define the terms effort and power of a governor. Also derive the expressions for effort and power in the case of a porter governor.

[20 marks]

Q.4 (c) A "0° - 60° - 120°" strain gauge rosette is bonded to the surface of a thin steel plate. Under a loading condition, the strain measurements are $\epsilon_A = 60\ \mu\epsilon$, $\epsilon_B = 135\ \mu\epsilon$, $\epsilon_C = 264\ \mu\epsilon$. Find the principal strains, their orientations, and the principal stress. Take $E = 210$ GPa and $\nu = 0.3$.

[20 marks]

Section : B

Q.5 (a) What are the desirable properties of moulding sand. Name and explain different additives used to achieve these properties.

[12 marks]

Desirable properties

① Refractoriness - It property of the moulding sand by virtue of which it withstand the high pouring temperature of molten metal without undergoing erosion

② ~~Perm~~ Permeability - property by virtue of which it allows the gases to escape.

③ Green strength - It is property by virtue of which it provides strength against the ~~metallostatic~~ force

(4) Flowability - It is property by virtue of which it does not provide any resistance against flow while ramming.

(5) Adhesiveness - Attract other atoms

(6) Cohesiveness - Attract own atom.

(7) collapsibility - It is property by virtue of which it does not provide any resistance again shrinkage

Additives

(1) mollases + dextrine - It increases strength and hardness

(2) sawdust and wood floor - It increases ~~surface finish~~ permeability and collapsibility

(3) coal dust - It increase ~~permeability~~ surface finish and flowability

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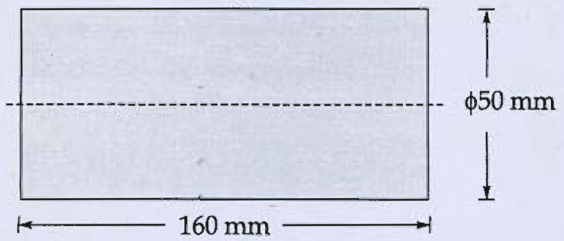
Q.5 (b) Estimate the actual machining time required for the component (C40 steel) shown in figure below. The available spindle speeds are 80, 120, 180, 290, 430, 700, 1200, 1800 and 3000 rpm. Use a roughing speed of 36 m/min and finish speed of 60 m/min. The feed of roughing is 0.36 mm/rev while that for finishing is 0.2 mm/rev. The maximum depth of cut for roughing is 2 mm. Finish allowance may be taken as 0.8 mm. Blank to be used for machining is 60 mm in diameter. Take overtravel allowance as 2 mm.



[12 marks]

Given (given) $V_r = 36\ m/min$ $V_f = 60\ m/min$

$D = 60mm$ $f_r = 0.36\ mm/rev$ $f_f = 0.2\ mm/rev$

$d_r = 2mm$ $A_f = 0.8mm$

$(l_o = 2mm)$

for roughing $V_r = \left(\frac{\pi D \times N}{60}\right)$

$\frac{36}{60} = \frac{\pi \times 60 \times N}{1000 \times 60}$ $N = 190.98$

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$180 < N < 290$

since N is more close to 180 rpm

hence $N_{selected} = 180 rpm$

$(t_m)_r = \left(\frac{l_e}{f_r \times N}\right) = \left(\frac{l + l_o}{f_r \cdot N}\right)$

$= \frac{160 + 2}{0.36 \times 180}$

$(t_m)_r = 2.5\ min$

$D_f = 50mm$

$D_i = 60mm$ and finishing allow $= 0.8mm$

$D_f' = 50 - 2 \times 0.8 = 49.2mm$

No. of roughing operation (n) = $\frac{60-49.2}{(2\times)}$

n = 5.4 ≈ 6

Hence (6) roughing operation

$t_r = 6\times 2.5 = 15$ min

$t_{finish} = \frac{l}{(f_f \cdot N)}$ $\left(v = \frac{\pi D N}{1000}\right)$

$60 = \frac{\pi \times 49.2 \times N}{1000}$

$= \frac{160+2}{0.2\times 430}$ N = 388.18

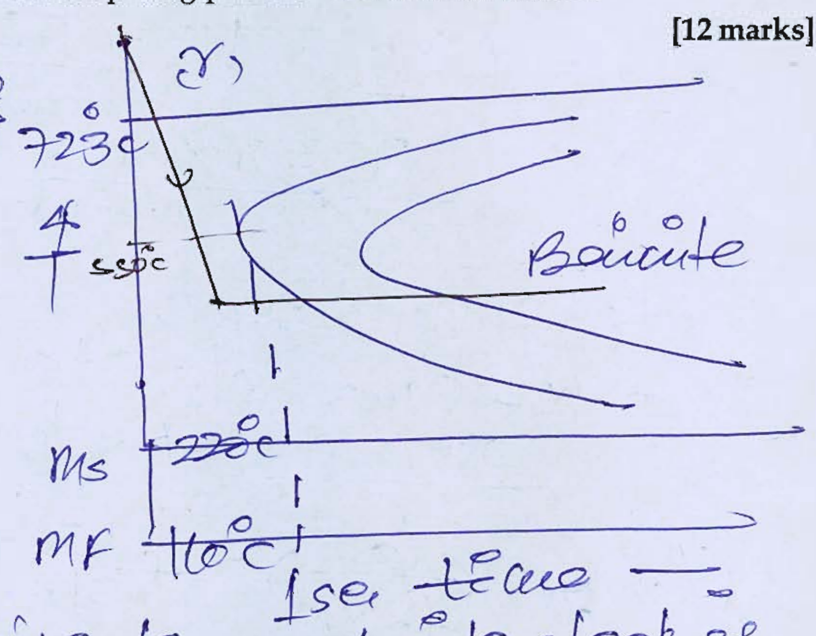
$t_f = 1.88$ min Hence N choose N = 430 rpm

total time = $t_r + t_f$
= 15 + 1.88 = 16.88 min

Q.5 (c) Explain austempering and martempering process with suitable sketch.

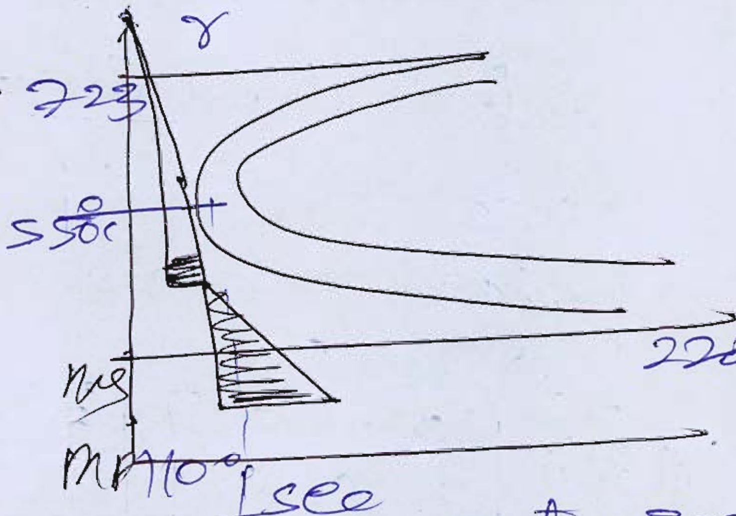
[12 marks]

Austempering



In austempering the austenite steel is cooled at rate greater than critical cooling rate to a temperature which below the nose of critical cooling rate and above the martensite start line (Ms) then hold for period of time until the cooling curve enter into the TTT diagram it result into the formation of Bainite.

Martempering



In this γ is cooled at the rate greater than critical cooling rate below nose of critical cooling and above Ms start time held for certain period of time such that core and surface comes at uniform temperature then it is cooled in molten bath at atmospheric temperature and result into Martensite formation —

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Q.5 (d) A point $P[7, 3, 1]^T$ is attached to a frame F_{noa} and is subjected to the following transformations:

(i) Rotation of 90° about the z-axis.

(ii) Followed by a rotation of 90° about the y-axis.

(iii) Followed by a translation of [4, –3, 7].

Find the coordinate of the point relative to the reference frame at the conclusion of transformations.

[12 marks]

(1) rotation about z axis (90°)

$$R_{(z,90)}\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R(z,90) = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 7 \\ 3 \\ 1 \end{bmatrix} = \begin{bmatrix} -3 \\ 7 \\ 1 \end{bmatrix}$$

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(2) rotation about y-axis (90°)

$$R_{y90} = \begin{bmatrix} \cos\theta & 0 & +\sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \end{bmatrix}$$

$$R(y,90) = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \end{bmatrix}\begin{bmatrix} -3 \\ 7 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 7 \\ 3 \end{bmatrix}$$

(3) translation of (4, –3, 7)

$$\left[\begin{array}{ccc|c} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 7 \\ \hline 0 & 0 & 0 & 0 \end{array}\right]\begin{bmatrix} 1 \\ 3 \\ 7 \\ 1 \end{bmatrix}$$

Do not write in this margin

$$= \begin{bmatrix} 5 \\ 0 \\ 14 \\ 1 \end{bmatrix}$$

Hence at the conclusion of transformation relative point coordinate $[5 \ 0 \ 14]^T$

Answer

Do not write in this margin

Q.5 (e) A pump acting as hydraulic actuator supplies oil at 0.002 m^3/s to a 50 mm diameter double acting cylinder and a rod diameter is 20 mm. If the load is 6000 N both in extending and retracting.

Find

(i) Piston velocity during the extension stroke and retraction stroke.

(ii) Pressure during the extension stroke and retraction stroke.

(iii) Power during the extension stroke and retraction stroke.

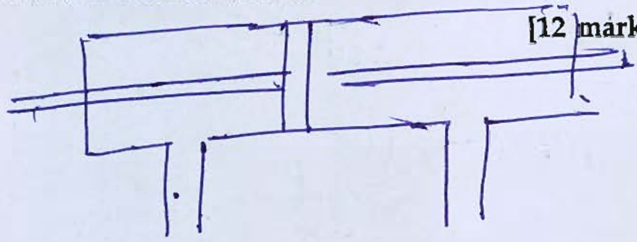
[12 marks]

$Q = 0.002\, m^3/s$

$D = 50\,mm$

$d = 20\,mm$

$P = 6000\,N$



(1) piston velocity ($Q = av$)

During ~~extension~~ retraction $0.002 = \frac{\pi}{4}(D^2 - d^2) \times v$

$0.002 = \frac{\pi}{4}(0.05^2 - 0.02^2) \times v_{ext}$

$v_{ext} = 1.2126$ m/s

during ~~extraction~~ $0.002 = \frac{\pi}{4}(0.05^2) \times v_{ext}$

$v_{ext} = 1.0185$ m/s

(2) $\text{pressure}_{extension} = \frac{P}{\frac{\pi}{4}(D^2)} = \frac{6000}{\frac{\pi}{4}(0.05)^2}$

$= 3.055$ MPa

pressure during retract $= \frac{P}{\frac{\pi}{4}(D^2 - d^2)}$

$= \frac{6000}{\frac{\pi}{4}(0.05^2 - 0.02^2)}$

$= 3.6378$ MPa

Power during extension = $P_{ext} \times (20)$
$= 3.055 \times 10^6 \times 2 \times 0.002$
$= 12.22$ kW

Power during refraction = $(P_{ret} \times 20)$
$= 3.6378 \times 10^6 \times 2 \times 0.002$
$= 14.55$ kW

8

Q.6 (a) The following are weekly sales data, in thousands of units, for micro-computer disks: 113, 101, 98, 107, 120, 132, 110, 117, 112 and 125 Use α = 0.2, α = 0.5 and α = 0.8 to produce an exponential smoothing model for these data. Which value of α produces better forecasts, assuming the initial forecast as 108? Explain.

[20 marks]

given $F(t+1) = \alpha D_t + (1-\alpha) F_t$

of initial $F_t = 108$

for $\alpha = 0.2$

	Demand	Forecast
1	113	108
2	101	109
3	98	107.4
4	107	105.54
5	120	105.816
6	132	108.65
7	110	113.32
8	117	112.656
9	112	113.524
10	125	113.219

$F_{n+1} = \alpha D_n + (1-\alpha) F_n$

$F_2 = (\alpha \times D_1 + (1-\alpha) F_1)$ = ~~0.2×108 + 0.8×108~~

$= 0.2 \times 113 + 0.8 \times 108$

$(F_2 = 109)$

$F_3 = \alpha D_2 + (1-\alpha) F_2$

$= 0.2 \times 107 + 0.8 \times 109$

$F_3 = 107.4$

$F_4 = \alpha D_3 + (1-\alpha) F_3$

$F_4 = 0.2 \times 98 + 0.8 \times 107.4$

$F_4 = 105.52$

$F_5 = \alpha D_4 + (1-\alpha) F_4$

$= 0.2 \times 107 + 0.8 \times 105.52$

$F_5 = 105.816$

$F_6 = \alpha D_5 + (1-\alpha) F_6$

$= 0.2 \times 120 + 0.8 \times 105.816$

$F_6 = 108.65$

$F_7 = \alpha D_6 + (1-\alpha) F_6$

$= 0.2 \times 132 + 0.8 \times 108.65$

$F_7 = 113.32$

$F_8 = \alpha D_7 + (1-\alpha) F_7$

$= 0.2 \times 110 + 0.8 \times 113.32$ $= F_8 = 112.656$

$F_9 = \alpha D_8 + (1-\alpha) F_8$

$= 0.2 \times 117 + 0.8 \times 112.656$

$F_9 = 113.524$

$F_{10} = \alpha D_9 + (1-\alpha) F_9$

$= 0.2 \times 112 + 0.8 \times 113.524$

$F_{10} = 113.21$

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If $\alpha = 0.5$

$F_2 = \alpha D_1 + (1-\alpha) F_1$

	Demand	Forecast
1	113	108
2	101	110.5
3	98	105.75
4	107	101.875
5	120	104.43
6	132	112.21
7	110	122.105
8	117	116.052
9	112	116.52
10	125	114.26

If $\alpha = 0.8$

$F_{n+1} = \alpha D_n + (1-\alpha) F_n$

$F_{n+1} = 0.8 D_n + 0.2 F_n$

	Demand	Forecast
1	113	108
2	101	112
3	98	103.2
4	107	99.04
5	120	105.408
6	132	117.08
7	110	129.016
8	117	113.803
9	112	~~116.36~~
10	125	112.87

from the above $\alpha = 0.2$, $\alpha = 0.5$ and $\alpha = 0.8$

If α is close to zero then it gives stable result/forecast which means that Demand and forecast are near to each other which can also read from the above table

Hence $\boxed{\alpha = 0.2}$ produce Better forecast

20

Q.6 (b) A carbide tipped turning tool with designation 0 - 10 - 6 - 6 - 8 - 90 - 1 mm (ORS) is used for orthogonal turning of a mild steel piece of 80 mm diameter at a cutting speed of 280 m/min and feed 0.25 mm/rev. If the cutting force is 180 kg and feed force is 100 kg and chip thickness is 0.32 mm, find shear angle, shear force, normal force acting on shear plane, friction force, coefficient of friction, friction angle and velocity of chip flow.

[20 marks]

given $\alpha = 10°$ $\phi = 90$

diameter (D) = 80 mm $V = 280$ m/min

$f = 0.25$ mm/rev $F_c = 180$ kg

$F_f = 100$ kg

$t_2 = 0.32$ mm

for orthogonal cutting $t_1 = f \cdot \sin\phi$

$t_1 = 0.25 \sin 90$

$t_1 = 0.25$

$r = \frac{t_1}{t_2} = \frac{0.25}{0.32}$

chip thickness ratio

shear angle (θ) $\tan\theta = \left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$

$\tan\theta = \frac{0.78125 \times \cos 10}{1 - 0.78125 \times \sin 10}$

$\theta = 41.67°$ #

shear force $(F_s = F_c\cos\theta - F_T\sin\theta)$

$\phi + \phi_s = 90$

$F_T = F_f \cdot \cos\phi_s$ $\phi_s = 0$

$F_T = F_f \cdot \cos 0° = 100$ kg

$F_s = 180\cos 41.67 - 100\sin 41.67$

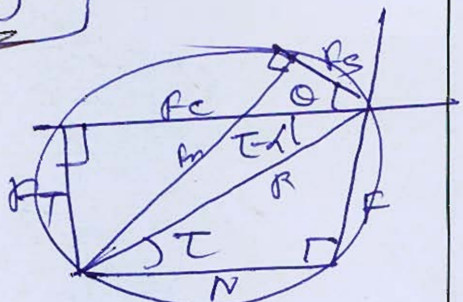
$F_s = 67.973$ kg #

Normal force on shear plane

$F_n = F_c\sin\theta + F_T\cos\theta$

$F_n = 180\sin 41.67 + 100\cos 41.67$

$F_n = 194.369$ kg #



$\tan(\tau - \alpha) = \left(\dfrac{F_T}{F_c}\right)$

$\tan(\tau - 10) = \left(\dfrac{100}{180}\right)$

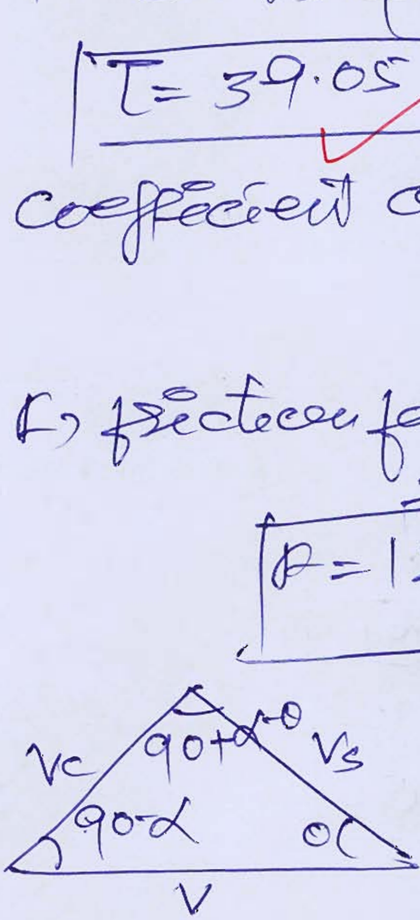
$\tau = 39.05°$ # friction angle

coefficient of friction $(\mu) = \tan\tau$
$= \tan 39.05$

$\mu = 0.8113$ #

(F) friction force $= F_c \sin\alpha + F_T \cos\alpha$
$= 180\sin 10 + 100\cos 10$

$F = 129.737$ kg #



$\dfrac{V}{\cos(\theta-\alpha)} = \dfrac{V_c}{\sin\theta} = \dfrac{V_s}{\cos\alpha}$

Vc = velocity of chip flow

$V_c = \dfrac{V\sin\theta}{\cos(\theta-\alpha)}$

$r = \dfrac{\sin\theta}{\cos(\theta-\alpha)}$

$V_c = V \cdot r$

$V_c = 280 \times \left(\dfrac{0.25}{0.32}\right)$

$V_c = 218.75$ m/min #

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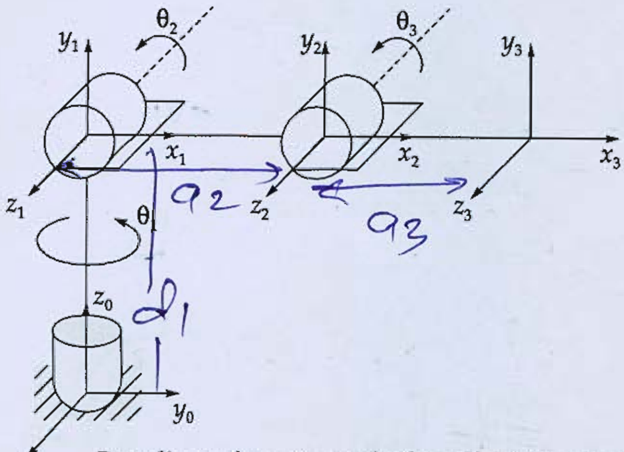
Q.6 (c) Consider frames attached to elbow manipulator as shown below. Manipulator has been pictured after rotation $(\theta_1, \theta_2, \theta_3) = (90°, 0, 0)$



Coordinate frames attached to elbow manipulator

Using forward-Kinematics:

(i) Set up a table of D-H parameters

(ii) Generate individual transformation matrices

(iii) Generate overall transformation matrix

Assume link lengths of a_2 and a_3 for links 2 and 3 respectively, and that the link 1 offset is d_1.

[20 marks]

D-H table

Link	a	α	d	θ
0-1	0	90	d_1	θ_1
1-2	a_2	0	0	θ_2
2-3	a_3	0	0	θ_3

Transformation matrix

$$^0T_1 = \begin{bmatrix} 0 & 0 & \cos\theta_1 & 0 \\ 0 & 0 & -\sin\theta_1 & 0 \\ 1 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$^1T_2 = \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 & 0 & a_2\cos\theta \\ \sin\theta_2 & \cos\theta_2 & 0 & a_2\cos\theta \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$ {}^{2}T_{3} = \begin{bmatrix} \cos\theta_3 & -\sin\theta_3 & 0 & a_3\sin\theta_3 \\ \sin\theta_3 & \cos\theta_3 & 0 & a_3\cos\theta_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$\theta_1 = 90$

$$ {}^{0}T_{1} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^{1}T_{2} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & a_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

6

$$ {}^{2}T_{3} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & a_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^{0}T_{3} = {}^{0}T_{1} \times {}^{1}T_{2} \times {}^{2}T_{3} $$

$$ = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & a_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & a_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

on solving we will get

overall transformation ${}^{0}T_{3}$ matrix.

Q.7 (a) A small project involves 7 activities and their time estimates are listed in the following table. Activities are identified by their beginning (i) and ending (j) node numbers.

Activity	Estimated Duration (Weeks)		
(*i-j*)	Optimistic	Most likely	Pessimistic
1 - 2	1	1	7
1 - 3	1	4	7
1 - 4	2	2	8
2 - 5	1	1	1
3 - 5	2	5	14
4 - 6	2	5	8
5 - 6	3	6	15

(i) Draw the network diagram of the activities in the project.

(ii) Find the expected duration and variance for each activity. What is the expected project length?

(iii) Calculate the variance and standard deviation of the project length. What is probability that the project will be completed:

1. at least 4 weeks earlier than expected time.
2. no more than 4 weeks later than expected time. Given:

Z	0.50	0.67	1.00	1.33	2.00
Prob.	0.6915	0.7486	0.8413	0.9082	0.9772

[20 marks]

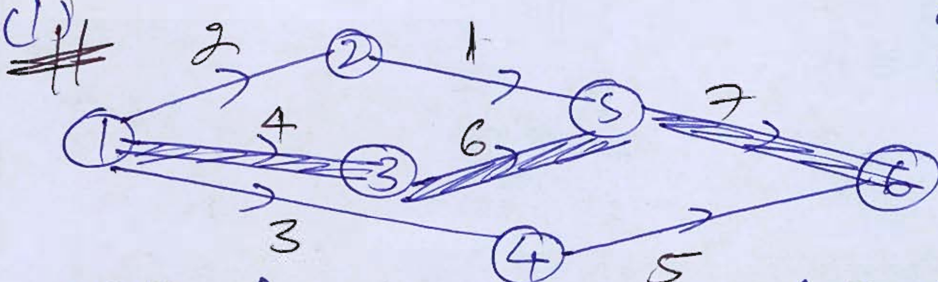
(i)

Activity	Estimated Duration t_o	t_m	t_p	$t_\mu = \frac{t_o + t_p + 4t_m}{6}$	$\sigma = \frac{t_p - t_o}{6}$	$V = \sigma^2$
1-2	1	1	7	2	6/6 = 1	1
1-3	1	4	7	4	6/6 = 1	1
1-4	2	2	8	3	6/6 = 1	1
2-5	1	1	1	1	0/6 = 0	0
3-5	2	5	14	6	12/6 = 2	4
4-6	2	5	8	5	6/6 = 1	1
5-6	3	6	15	7	12/6 = 2	4

t_μ = expected duration

V = variance

(i)



Critical path 1-3-5-6

(ii) expected project length = 17 weeks

(iii) variance of project length

$V = V_{1-3} + V_{3-5} + V_{5-6}$

$V = 1 + 4 + 4$ $\boxed{v = 9}$

standard deviation $\boxed{\sigma = \sqrt{v} = \sqrt{9} = 3}$

① Probability $= \frac{T_s - T_\mu}{\sigma}$

$T_s = (T_\mu - 4) = 13$

$P_{(z)} = \frac{13-17}{3}$ $\boxed{P_{(z)} = -4/3}$

$\boxed{P(z) = 1 - 0.9082 = 0.0918}$

(ii)

(2) No more than 24 week date tacy expected

$z = \frac{T_S - T_\mu}{(\sigma)} = \frac{21-17}{(3)}$, i.e. $T_S = 17+4 = 21$

$z < 4/3$

$P(z) = 0.9082$

20

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Q.7 (b) The following Taylor tool life equation for carbide tool, steel work piece pair is obtained experimentally $VT^{0.2} = 600$ where V is in m/min and T is in min. A batch of 1200 steel parts, each 100 mm in diameter and 200 mm in length, is to be rough turned using a feed of 0.15 mm/rev. If the cost per edge of the throw away carbide insert is ₹60, time required to reset the cutting edge is 1 min and the total machining cost (including operator cost) is ₹360 per hour, calculate

(i) optimum cutting speed for minimum cost.

(ii) the corresponding tool life.

(iii) total production cost if time taken to load and unload the component is 3 min, and the initial setup time is 2 hours, and

(iv) total production time for the given batch.

[20 marks]

given $VT^{0.2} = 600$ $C_e = ₹60$

tool changing time $t_c = 1$ min

$C_m = 360$ per hour $= ₹6$ per min

① optimum cutting speed for minimum cost

$$V_{op} = \frac{C}{\left[\left(\frac{1}{n}-1\right)\left(t_c + \frac{C_e}{C_m}\right)\right]^n}$$

$$V_{op} = \frac{600}{\left[\left(\frac{1}{0.2}-1\right)\left(1+\frac{60}{6}\right)\right]^{0.2}}$$

$V_{op} = 281.488$ m/min #

② Tool life

$(VT^{0.2} = 600)$

$(281.488)(T^{0.2}) = 600$

$T_{op} = 44$ min #

(iii) $t_{loading} + t_{unloading}$ = idle time
($t_i = 3$ min)
$t_{setup} = 2$ hr

$t_{idle} = 2\times60+3$
Total = 123 min

Total production cost

$TPC = C_m \times T_m + C_m \times T_i + C_e \times \frac{T_m}{T} + C_m \times \frac{T_m}{T} \times t_c$

T_m = machining time $T_m = \frac{L}{(fN)}$

$T_m = \frac{200}{0.15 \times \left(\frac{1000 \times V}{\pi D}\right)} = \frac{200}{0.15 \times \frac{1000 \times 281.488}{\pi \times 100}}$

$T_m = 1.488$ min ~~per part~~ for 1200 parts

$T_m = 1.488 \times 1200 = 1785.71$ min

$TPC = 6 \times 1785.71 + 6 \times 123 + 60 \times \frac{1785.71}{44} + 6 \times \frac{1785.71}{44} \times 1$

$TPC = 14130.85$ ₹ #

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(iv) Total production time

$\left(T_{idle} + T_m + \frac{T_m \times t}{T}\right)$

$\Rightarrow 123 + 1785.71 + \frac{1785.71}{44} \times 1$

$T_{pt} = 1949.294$ min #

Q.7 (c) Define corrosion. Write names of different type of corrosion. Briefly explain selective leaching. Name different type of methods to control corrosion and explain cathodic protection.

[20 marks]

It is defined as the process of degradation/ deterioration of the metal/material surface when exposed to certain environment.
Every material have some galvanic potential when arranged in galvanic series according to their Redox potential. When Zn is placed in water from the zinc ion start coming out in the soln the rate at which Zn^{2+} out in the soln is called corrosion ion coming into rate.

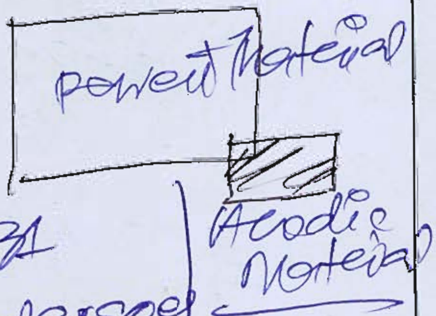
types of corrosion

1. Galvanic corrosion
2. Crevice corrosion
3. pitting
4. selective leaching
5. stress corrosion
6. uniform corrosion
7. fillform corrosion.

selective leaching – when the material is exposed to the environment (generally acidic) and material behaves as anode material then in certain span of time material start coming out from parent material (ore) due to corrosion and the process is called selective leaching

Control methods ① Cathodic protection
② By connecting Battery
③ By painting the surface in case of crevice corrosion
④ By using rubber gasket in place of steel/metal gasket

Cathodic protection –



every material exist in the nature will have anodic material. And it is Anode which undergoes the corrosion. Hence by attaching the Anodic Material to the parent material the corrosion can be prevented b/z the Anode will corrode after some time it is replaced with new one.

By connecting Battery – Corrosion is nothing but the rate at which electron comes out from the material. By providing extra electron using Battery corrosion / corrosion rate can be prevented and decreased.

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Q.8 (a) Explain development of microstructure in isomorphous alloys for non equilibrium cooling.

[20 marks]

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Q.8 (b) A shopkeeper estimates the annual requirement of an item as 2,000 units. He buys it from his supplier at a cost of Rs. 10 per item and the cost of ordering is Rs 50 each time he orders. If the stockholding costs are 25 per cent per year of stock value, how frequently should he replenish his stocks? Further, suppose the supplier offers a 10 per cent discount on orders between 400 and 699 items, and a 20 per cent discount on orders exceeding or equal to 700. Can the shopkeeper reduce his costs by taking advantage of either of these discounts?

[20 marks]

Q.8 (c) Explain the following NDT techniques:

(i) Vibration Monitoring

(ii) Wear debris analysis

(iii) Thermography

(iv) Visual inspection

[20 marks]

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Space for Rough Work

Space for Rough Work