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ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Mechanical Engineering

Test-6 : Production Engineering and Material Science

+ Mechatronics and Robotics

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	48
Q.2	19
Q.3	–
Q.4	–
Section-B	
Q.5	30
Q.6	32
Q.7	–
Q.8	10
Total Marks Obtained	139

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

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IMPORTANT INSTRUCTIONS

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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 : Production Engineering and Material Science + Mechatronics and Robotics

1 (a) Mild steel is being machined at a cutting speed of 200 m/min with a tool of rake angle 10°. The width of cut and uncut thickness are 2 mm and 0.2 mm respectively. If the average value of the coefficient of friction between the tool and chip is 0.5 and shear stress τ_s of the work material is 400 N/mm^2. Determine:

1. Shear angle
2. The cutting and the thrust component of machine force

By using

(i) Merchant's theory

(ii) Lee and Shaffer relation

[12 marks]

→ Data. $V = 200$ m/min $\quad \alpha = 10°\quad b = 2$mm

$t = 0.2$mm

$\tau_s = 400$MPa $\quad \mu = 0.5$.

(i) Merchant's theory.

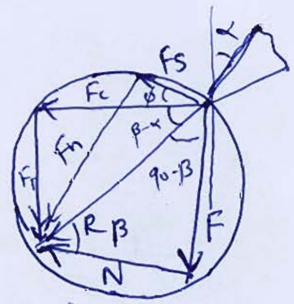
$\tan\beta = \mu = 0.5$, $\quad \beta = 26.565°$, $\quad \alpha = 10°$.

$\phi = 45 + \frac{\alpha}{2} - \frac{\beta}{2}$, $\quad \phi = 45 + \frac{10}{2} - \frac{26.56}{2}$

$\boxed{\phi = 36.72°}$

By force relation using merchant theory.

$F_s = \tau_s \frac{bt}{\sin\phi}$



$F_s = 400 \times \frac{2 \times 0.2}{\sin(36.72)} = 267.6$ N.

$\cos(\phi + \beta - \alpha) = \frac{F_s}{R}$, $\quad R = \frac{267.6}{\cos(36.76 + 26.56 - 10)}$

$R = 447.9821$ N.

$F_c = R\cos(\beta - \alpha) = 447.982\cos(26.56 - 10)$

$\boxed{F_c = 429.4 \text{ N}}$ Ans — cutting force

$F_t = R\sin(\beta - \alpha)$

$\boxed{F_t = 127.6834 \text{ N}}$ thrust force. Ans

By Lee & Shaffer relation

$\phi = 45 + \alpha - \beta$, $\phi = 45 + 10 - 26.56$

$\phi = 28.44.$

$F_s = \frac{\tau_s bt}{\sin\phi}$, $R = \frac{F_s}{\cos(\phi+\beta-\alpha)} = \frac{335.96}{\cos(28.44+26.56-10)}$

$F_s = 335.96$ N.

$R = 475.1191$ N

$F_c = R\cos(\beta-\alpha)$

$F_c = 445.412$ N → cutting force — Ans

$F_t = R\sin(\beta-\alpha)$

$F_t = 135.418$ → thrust force

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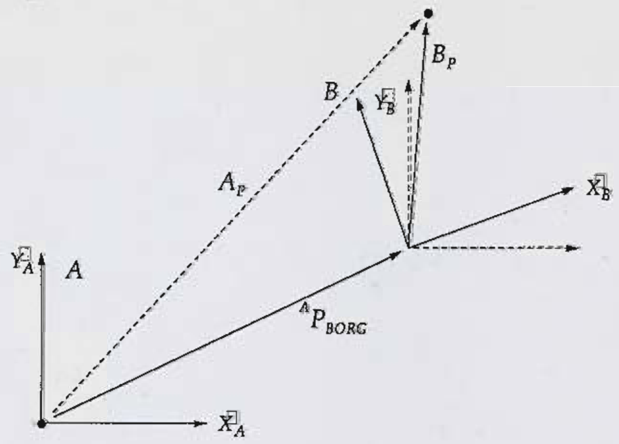
Q.1 (b) Figure shown below represents a frame {B}, which is rotated relative to frame {A} about Z-axis by 30 degrees, translated 10 units in $\hat{X}_A$ and translated 5 units in $\hat{Y}_A$. Find ${}^{A}P$, where ${}^{B}P = [3, 7, 0]^T$.



Frame (B) rotated and translated

[12 marks]

→ $\vec{F}^{A} = T(10,5,0)R_z(30^\circ)$

$\vec{F}^{f} = \text{Trans}[10,5,0]\,R_z(30)\,\vec{F}_g$

← fixed Ref. sequence.

$$\vec{F_1} = \begin{bmatrix} 1 & 0 & 0 & 10 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 7 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 13 \\ 12 \\ 0 \\ 1 \end{bmatrix}$$

$$\vec{F_2} = R_z(30)\vec{F_1}$$

$$= \begin{bmatrix} \cos(30) & -\sin(30) & 0 & 0 \\ \sin(30) & \cos(30) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 13 \\ 12 \\ 0 \\ 1 \end{bmatrix}$$

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$$= \begin{bmatrix} 0.866 & -0.5 & 0 & 0 \\ 0.5 & 0.866 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 13 \\ 12 \\ 0 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.866\times 13 + (-0.5)\times 12 + 0\times 0 + 0\times 1 \\ 0.5\times 13 + 0.866\times 12 + 0\times 0 + 0\times 01 \\ 0 \quad 0 \quad 1\times 0 + 0 \\ 0 \quad 0 \quad 0 \quad 0 \end{bmatrix}$$

$$A_p = \begin{bmatrix} 11.258 - 6 \\ 16.892 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 5.258 \\ 16.258 \\ 0 \\ 0 \end{bmatrix}$$

Ans

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Q.1 (c) Titanium has an HCP unit cell for which the ratio of the lattice parameters (c/a) is 1.58. If the radius of the Ti atom is 0.1445 nm, then determine the unit cell volume, the density of Ti and compare it with the literature value of 4.51 g/cm^3.
[Atomic weight of Ti = 47.87 gm/mol]

[12 marks]

Given $\frac{c}{a} = 1.58$, $R = 0.1445 \times 10^{-9}$ m

Awt (Ti) = 47.87 gm/mole.

Volume of unit cell in HCP = $\frac{1}{2} \times A_T \times C$

$= \frac{1}{2} \times \frac{\sqrt{3}}{4} \times a^2 \times C \times 6 = \frac{6}{8} \cdot \frac{\sqrt{3}}{4} a^2 \times c$

$= \frac{3}{2} \cdot \sqrt{3}\, a^2 \times c = \frac{3}{2} \sqrt{3} \times a^2 \times 1.58a$ — (A)

and from Geometry. $a = 2R$, $a = 2 \times 0.1445 \times 10^{-9}$

$a = 2.89 \times 10^{-10}$ m

Put in (A) ⇒ Volume of unit cell $= \frac{3\sqrt{3}}{2} \times (2.89 \times 10^{-10})^3 \times 1.58$

Volume = 9.90837×10^{-29} m^3

Ans

theoretical density = $\frac{N_{avg} \times Awt}{(A.No) \times \text{Volume of unit cell}}$

$(N_{avg})_{HCP} = 6$, Awt = 47.87, A.NO = 6.023×10^{23}

$(\rho)_t = \frac{6 \times 47.87}{6.023 \times 10^{23} \times 9.90837 \times 10^{-29} \times 10^6}$

$\rho_t = 4.8128$ g/cm^3 → theoretical.

considering the $(\rho)_{literature} = 4.51$ g/cm^3

$4.51 = \frac{(N_{avg})' \times 47.87}{6.023 \times 10^{23} \times 9.90837 \times 10^{-29} \times 10^6}$

$N_{avg} = 5.62$ atoms.

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In seed leoatux density $N'_{ay} = 5.622 < N_{avg}$.

hence more voncany observed in likoatux density titanium.

1 (d) State:

(i) Gibbs phase rule and lever rule

(ii) Isomorphous system

(iii) Peritectic reaction in steel

[12 marks]

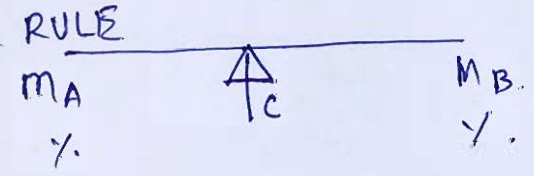
(i) Gibbs phas Rule

$$P + F = C + 1$$

where as P = no of phasey
F = Degree of freedom
C = no. of component.

→ this rule used to findout the number of Degree of freedom and value obtaind i.e. defined minimum parameter required to stak (or) defined the system.

(ii)(a) LEVER RULE

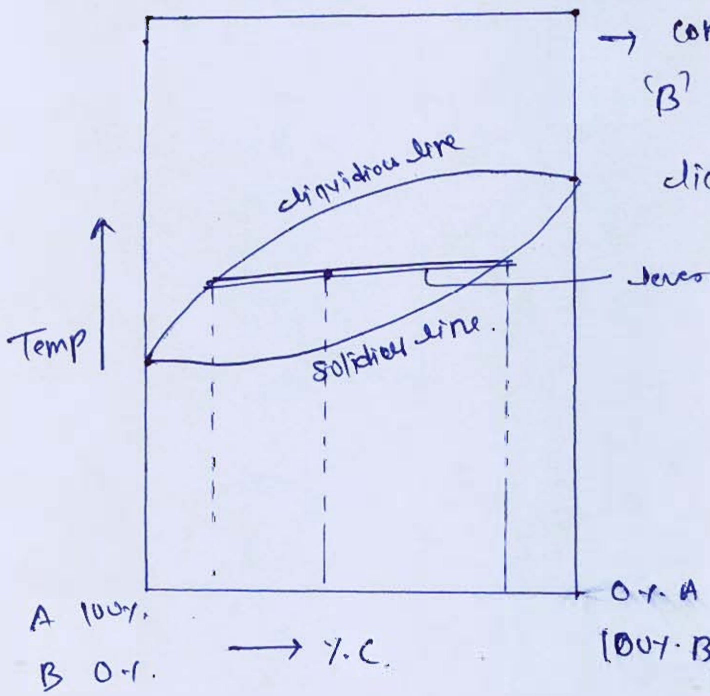


By levor Rule we can find the composition of phasy present in the Fe-C diagram.

M A — Δ x — MB
Y_1 — Y_2

$M_A = \frac{Y_2 - x}{Y_2 - Y_1}$ ~~MA+MB~~ $M_A + M_B = 1$

(iii) ISOMORPHOUS SYSTEM



→ component A and component 'B' is completely solution in liquid as well as solid state.

levor line.

(iii) PERITECTIC REACTION.

In this Reaction one liquid component combines with solid component and botho decomposed to solid component upon cooling.

→ This reaction reversible in nature.

eg $L + \gamma \rightleftharpoons Fe_3C$

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1 (e) How are grinding operations or grinding machines classified based on the type of surface produced? Explain with neat sketch.

[12 marks]

CLASSIFICATION.

(a) On the basis of direction of Rotor axis.

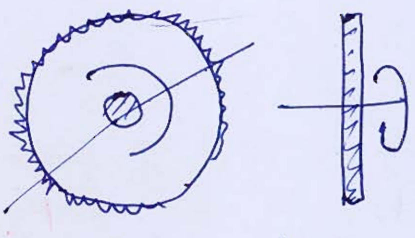
1) Horizontal Grinder

2) vertical grinder

(b) centerless grinding machine.

(c) surface Grinder Grinder.

i) Horizontal grinder machine

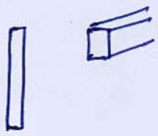


fined cut surface produced

eg.

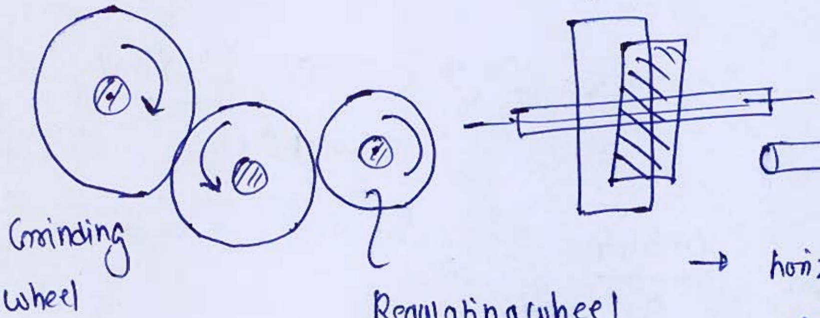
→ slab, square fine finis

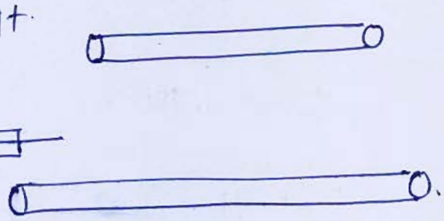
rods



ii) centerless Grinding

5 to 10° tilt





→ horizontal vertical cylindrical surface bars can be produced

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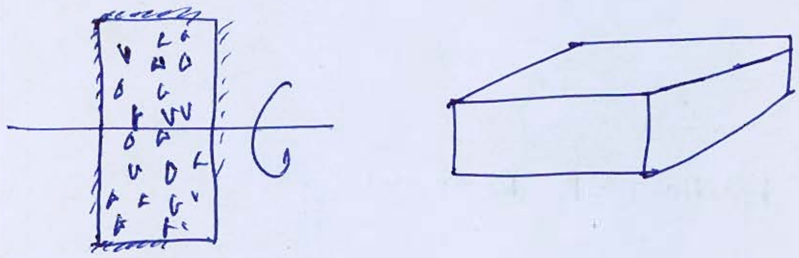
iii) surface Grinder .



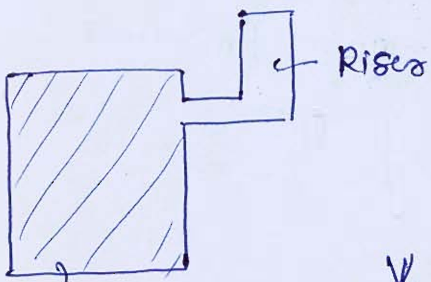
flat surface finish (high fined finish) surfaces can be produced

8

Q.2 (a) Calculate the dimensions of a cylindrical side and top riser used for a steel casting of 30 cm × 18 cm × 12 cm dimension. The volume shrinkage can be taken as 7%. Derive all the relations used for solving the question.

[20 marks]

→ consider cylindrical side



3

$H = D$.

$\frac{V}{A} = \left(\frac{A}{V}\right)_{casting} = 7\% \left(\frac{A}{V}\right)_{Riser}$

$\frac{2 \times \frac{\pi}{4} \times D^2 + \pi D H}{\frac{\pi}{4} \times D^2 H} = \frac{2(30 \times 18 + 18 \times 12 + 12 \times 30)}{30 \times 18 \times 12}$

$\left(\frac{\frac{\pi}{2} \times D^2 + \pi D^2}{\frac{\pi}{4} \times D^3}\right) = \frac{0.344}{0.07}$

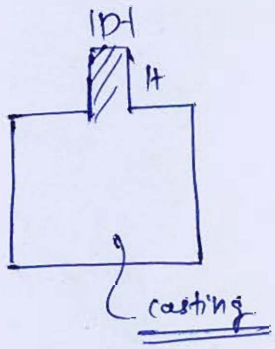
$$\frac{\frac{\pi}{2}+\pi}{\frac{\pi D}{4}} = \frac{0.07}{0.344} = 4.914 \Rightarrow \frac{1}{13.698} = \frac{D}{4}$$

D = 1.22 cm
H = 1.22 cm

Ans

Dia of riser = ~~6.48 cm~~ ~~3.83 cm~~
Height of Riser = ~~6.48 cm~~ ~~3.83 cm~~

→ considering Top Riser



$$H = \frac{D}{2}$$

$$\left(\frac{A}{V}\right)_{casting} = 0.07\left(\frac{A}{V}\right)_{Riser}$$

$$0.344 = 0.07 \times \frac{\left(\frac{\pi}{4}D^2 + \frac{\pi D \cdot D}{2}\right)}{\frac{\pi}{4}\times D^2 \times \frac{D}{2}}$$

$$4.914 = \frac{\pi D^2\left(\frac{1}{4}+\frac{1}{2}\right)}{\pi D^2\left(\frac{1}{4}\times\frac{D}{2}\right)} = \frac{0.75}{\frac{D}{8}}$$

D = 1.22 cm
H = 2.44 cm

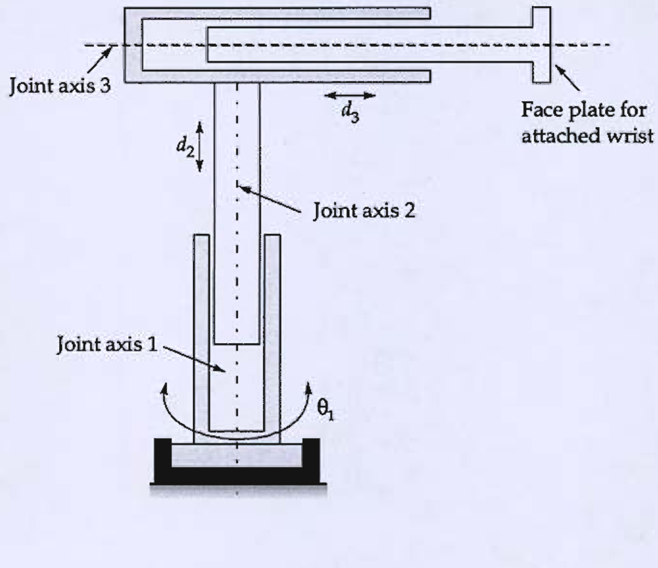
Ans

2 (b) For the given 3-link cylindrical manipulator.

1 Assign the co-ordinate frames based on D-H representation.

2. Make the D-H parameter table.

3. Prepare the individual and the final composite transformation matrix.



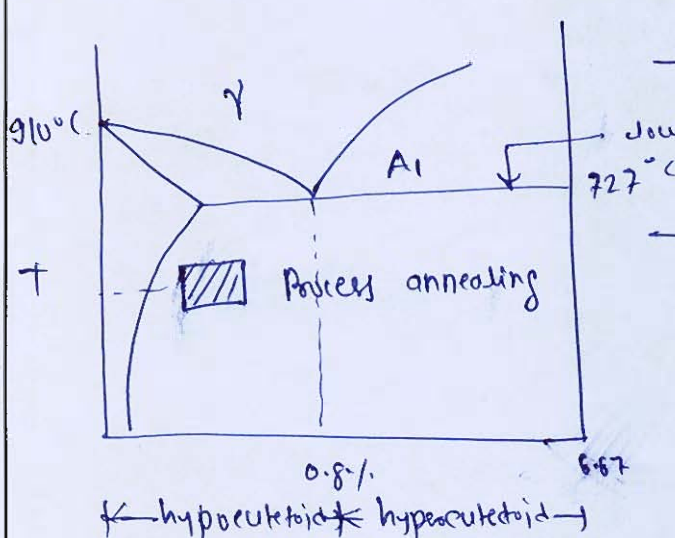
[20 marks]

Q.2 (c) Explain the following heat treatments processes:

1. Process annealing
2. Full annealing
3. Normalizing
4. Spheroidizing

[20 marks]

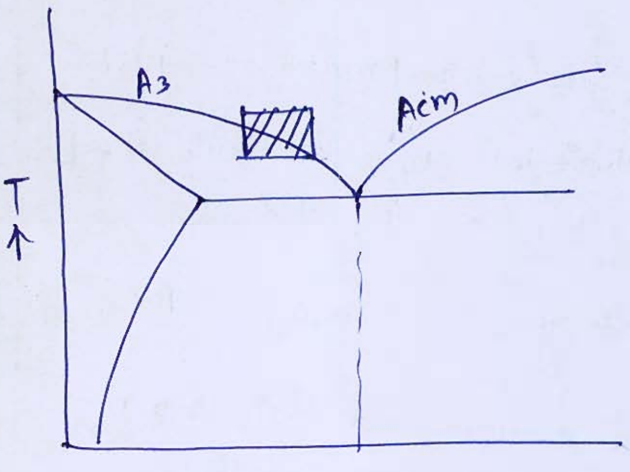
→



→ Done at below lower critical temp ie A_1 line

→ main aim of process annealing is to reduced the internal stressed produced.

2. Full Annealing ~~Normalizing~~



→ Done at above upper critical temp i.e 50 °C Above lower critical temperature line

→ then cooled in air (or) furnace depends upon application

→ 3.) Normalising is the final heat treatment process

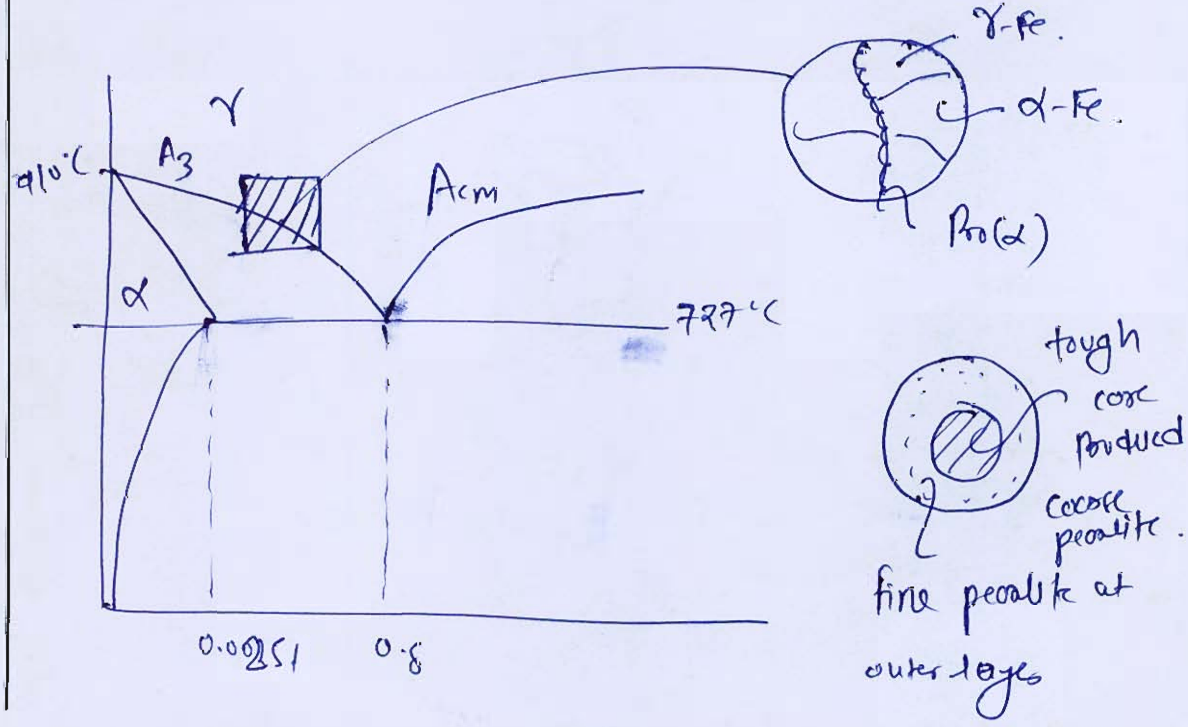
↳ performed at upper critical temperature line

3. i.e in hypoeutectoid steel

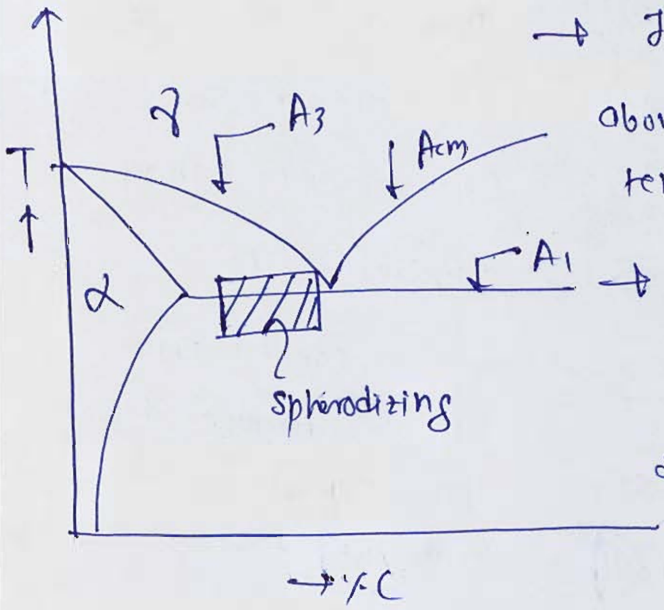
→ hold at that temperature for sufficient time

→ cooling can be done in air

→ Resulting microstructure obtained is fine pearlite at outer surface and coarse pearlite inside



4.) Spheroidizing



→ It is performed at just above the ~~upper~~ ~~to~~ lower critical temperature i.e 730°C

→ generally employed for medium and high carbon steel to improve the machinability

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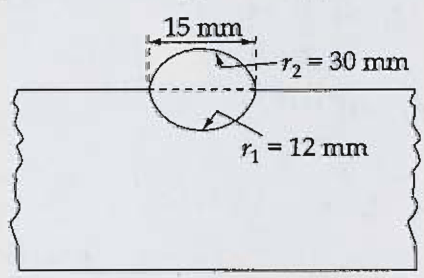
Q.3 (a) The cross-section of weld bead is shown in figure. The profile of the bead and the fusion zone are taken circular for convenience. Bead width and radii of curvature of circular profiles are shown in figure. What is percentage dilution?



[20 marks]

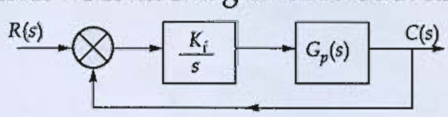
Q.3 (b) What is corrosion, explain with the help of electrochemcial reactions?

[20 marks]

Q.3 (c) A closed-loop system has the process transfer function:

$$G_p(s) = \frac{1}{s(s+4)}$$

and is used in conjunction with an integral controller as shown below:



Obtain the following

1. The system type
2. The steady-state errors when used with a step input and with a ramp input.
3. Evaluate the stability of the system in relation to a system with proportional control.
4. Evaluate the stability with integral control

[20 marks]

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(a) A continuous and aligned fibre-reinforced composite is to be produced consisting of 30 vol% aramid fibre and 70 vol% of a polycarbonate matrix: Mechanical characteristics of these material are as follows:

	Modulus of elasticity	Tensile strength
Aramid fibre	131 GPa	3600 MPa
Polycarbonate	2.4 GPa	65 MPa

Assume that the composite as described above has the cross sectional area of 320 mm^2 and subjected to a longitudinal load of 44.5 kN. Calculate

1. The fibre matrix load ratio.
2. The actual loads carried by both fibre and matrix phases.
3. The magnitude of the stress on each of the fibre and matrix phases.
4. What strain is experienced by the composite?

[4 × 5 = 20 marks]

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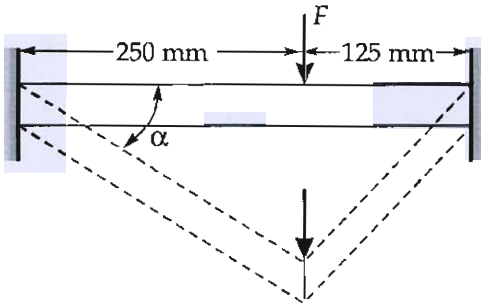
(b) A 375 mm long sheet with a cross-sectional area of 5×10^{-4} m^2 is stretched with a force, F, until $\alpha = 20°$. The material has a true stress-true strain relationship as, $\sigma = (700 \text{ MPa})\epsilon^{0.3}$. Calculate:



(i) The total workdone, ignoring end effects and bending.

(ii) What is α_{max} before necking begins?

[20 marks]

.4 (c) An annealed low carbon steel strip (K = 350 MPa and n = 0.26) 200 mm wide and 10 mm thick, rolled to a thickness of 6 mm. The roll radius and coefficient of friction are 150 mm and 0.1 respectively.

1. Calculate the roll pressure at the entrance to the rolls, at the neutral point and at the exit of rolls.
2. Find the magnitude of back tension required to make the rolls begin to slip.

   Use Von Mises criterion.

[20 marks]

Section B : Production Engineering and Material Science + Mechatronics and Robotics

Q.5 (a) Composition of a nickel superalloy is as follows : Ni = 70.0%, Cr = 20.0%, Fe = 5.0% and rest titanium. Calculate rate of dissolution (in mm/min) if the area of the tool is 1600 mm^2 and a current of 1500 A is being passed through the cell. Assume dissolution to take place at lowest valency of elements.

$$A_{Ni} = 58.71 \text{ gm/mol}, \rho_{Ni} = 8.9 \text{ gm/cc}, Z_{Ni} = 2/3$$
$$A_{Cr} = 51.99 \text{ gm/mol}, \rho_{Cr} = 7.19 \text{ gm/cc}, Z_{Cr} = 2/3/6$$
$$A_{Fe} = 55.85 \text{ gm/mol}, \rho_{Fe} = 7.86 \text{ gm/cc}, Z_{Fe} = 2/3$$
$$A_{Ti} = 47.9 \text{ gm/mol}, \rho_{Ti} = 4.51 \text{ gm/cc}, Z_{Ti} = 3/4$$

where symbol A, ρ and Z are atomic mass, density and valency of elements respectively.

[12 marks]

→ Data, Ni = 70%, Cr = 20%. Fe = 5%. Ti = 5%

A = 1600 mm^2 I = 1500 A Assume → low valency

∴ composition of density.

$$\left(\frac{1}{\rho}\right)_{alloy} = \frac{0.7}{8.9} + \frac{0.2}{7.19} + \frac{0.05}{7.86} + \frac{0.05}{4.51}$$

$$(\rho)_{alloy} = 8.0699 \text{ gm/cc}$$

∴ composition of chemical equivalent $\left(e = \frac{\text{Awt}}{\text{Valency}}\right)$

$$\left(\frac{1}{e}\right)_{alloy} = \frac{2 \times 0.7}{58.71} + \frac{2 \times 0.2}{51.49} + \frac{2 \times 0.05}{55.85} + \frac{3 \times 0.055}{47.9}$$

$$e = 27.425 \text{ gm/mol}$$

MRR of superalloy $= \frac{eI}{F\rho} = \frac{27.425 \times 1500}{91500 \times 8.0699}$

∴ F → faraday const
↳ 96500 columb.

MRR = 0.05282 $\frac{cm^3}{sec}$

$$MRR = 0.05282 \times 10^3 \times 60 \ \frac{mm^3}{min}$$

$$MRR = 3169.628 \ \frac{mm^3}{min}$$

$$\therefore \text{rate of dissolution} = \frac{3169.628}{1600} \ mm/min$$

$$\boxed{\text{dissolun} = 1.98 \ mm/min}$$

Ans

12

Q.5 (b) Explain the principle of abrasive water-jet machining using suitable schematic diagram. Write the advantages and applications of AWJM.

[12 marks]

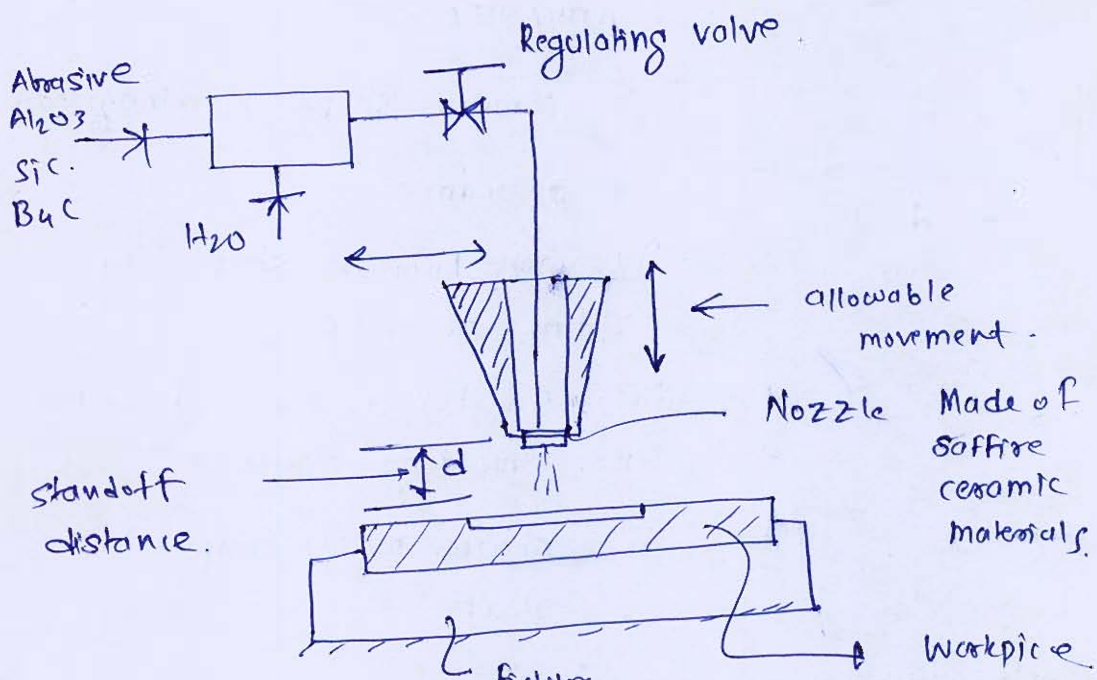


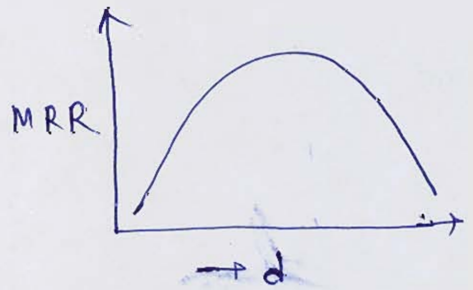
Fig.(a) Abrasive water Jet Machining.

1) In (AWJM) abrasive particles such as alumina, SiC and B_4C are added to increase the material removal rate

2) Sufficient standoff distance has to maintained to maintained MRR

3) Beyond 0.6 - 0.18 mm material removal rate of AWJM decreases

4) Water Pressure with abrasive particles can be adjusted by pressure regulating valve.



ADVANTAGES

i) complex shape machining can be done
ii) hole Intricate shape with fine accuracy
(iii) No fumes produced hence no shielding required
(iv) cheaper process compare to others

Application

i) Hole in carburator of ~~di~~ petrol engine
(ii) small hole in ~~#~~ Injector can be produced
(iii) cavity in heavy duty die can be produced.

(1)

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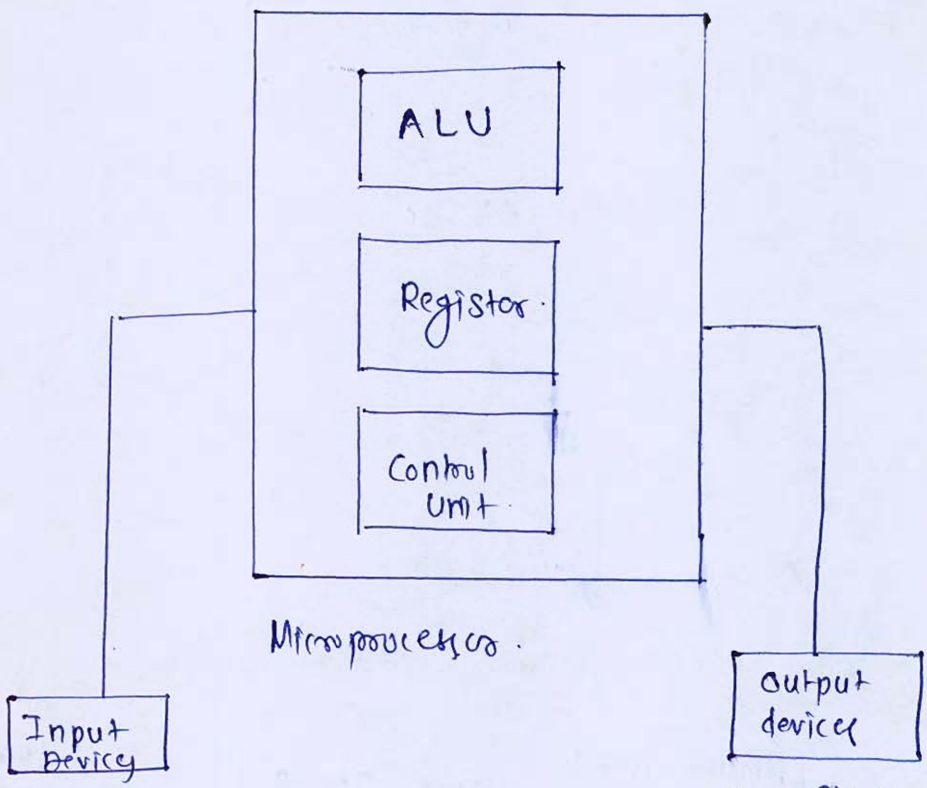
5 (c) Draw the block diagram of a microcomputer and explain briefly the three segments (ALU, register and control unit) of a microprocessor. What are the application areas of microprocessor?

[12 marks]



• keyboard
• mouse

eg. Display, Printer, ...

3

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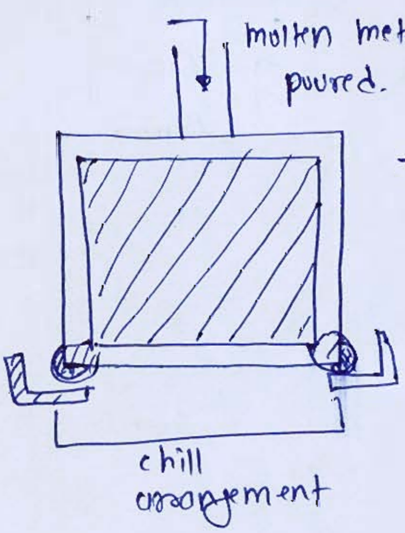
Q.5 (d) Explain hot spots and hot tears in metal casting, their formation mechanisms and causes. Suggest preventive measures and illustrate with a neat schematic diagram.

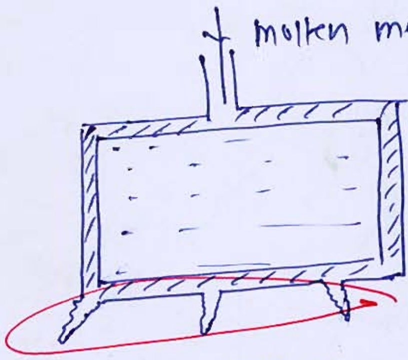
[12 marks]



HOT SPOTS

→ when hot molten metal poured into the moulding cavity, at the corner of the casting hot spot generated.

→ Due to hot spot metal (molten) remain in molten state and casting cannot be produced.



HOT TEARS

→ Due to improper ramming of moulding sand, the cracks are produced at the corner sight of casting

→ Due to temperature difference b/w molten metal and ~~to~~ available air medium cracks are genrated.

Preventive mesures for Hot Spot

→ By providing chills at the corner side of high thermal conductivity material eg copper attachment of chill reduce Hot spot.

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Preventive measures for Hot tears.

→ Befor pouring molten metal, Proper ramming should be done. so the continuous large area available

→ using Jolting and heavy die Pressure such defects can be avoided

Q.5 (e) A robot arm having one DOF (revolute joint) is stationary at $\theta = 0°$. It is required to move it to $\theta = 60°$ in 5 seconds. Find the coefficients of a cubic equation that accomplishes this motion and brings the manipulator to rest at the goal point.

[12 marks]

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Q.6 (a) An accelerometer is designed with a seismic mass of 50 gram, a spring constant of 5000 N/m, and a damping constant of 30 N.s/m. If the accelerometer is mounted to an object experiencing displacement $x_{in}(t) = 5 \sin(100t)$ mm, find each of the following:

(i) The actual acceleration amplitude of the object.

(ii) The amplitude of the steady state relative displacement between the seismic mass and the housing of the accelerometer.

(iii) The acceleration amplitude, as measured by the accelerometer.

(iv) An expression for the steady state relative displacement of the seismic mass relative to the housing as a function of time $[x_r(t)]$

[20 marks]

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Q.6 (b) By drawing the iron-carbon diagram observe the following for 1.0 kg of austenite containing 1.15 wt% C cooled to just below 727°C:

(i) What is the proeutectoid phase?

(ii) How many kilogram each of total ferrite and cementite is formed?

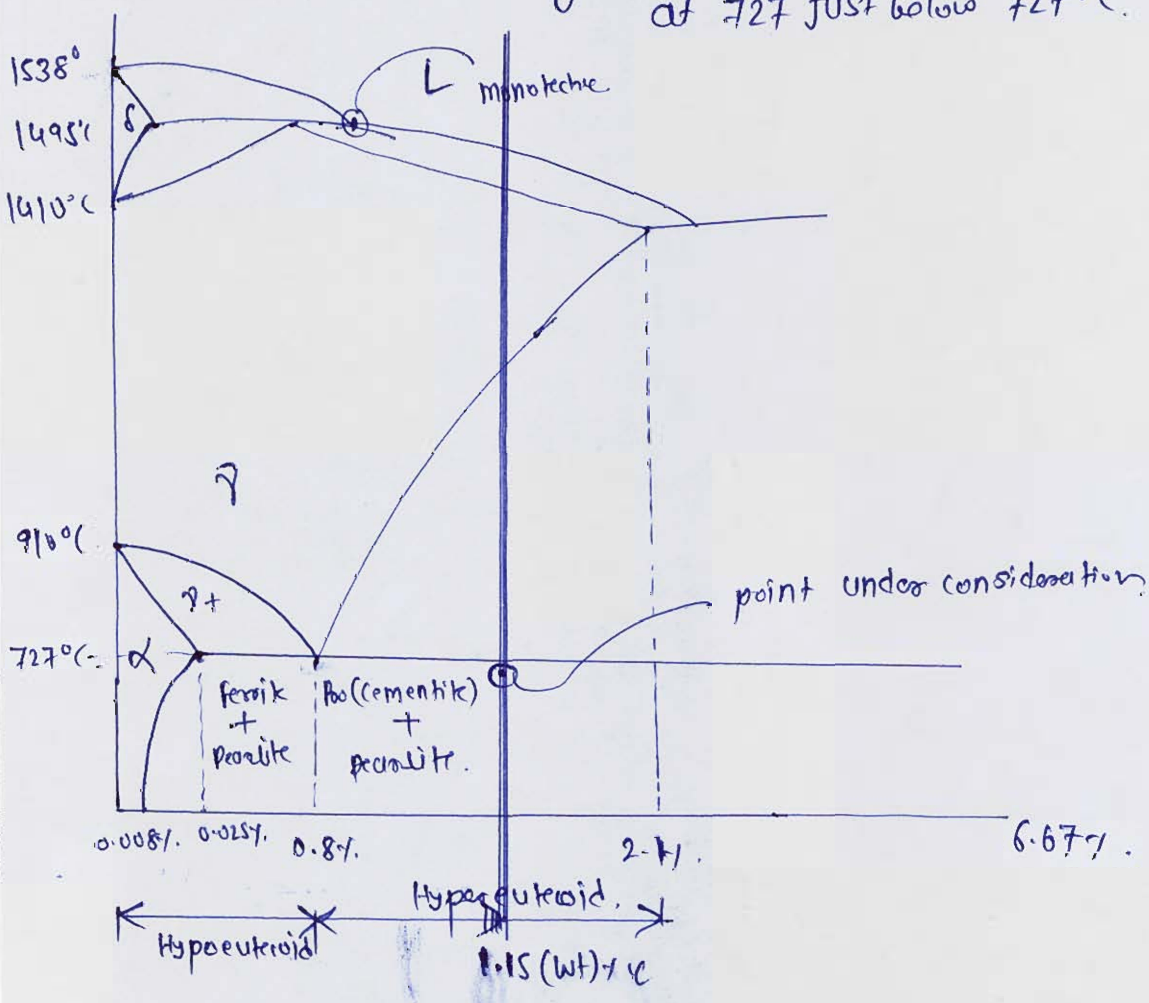
(iii) How many kilogram each of pearlite and the proeutectoid phase is formed?

(iv) Schematically sketch and label the resulting microstructure.

[20 marks]

→ Given data $\gamma = 1\,kg$ $C = 1.15$ Wt% C

at 727 just below 727°C.



(i) Proeutectoid phase is = Fe_3C [Cementite]

(ii) Total ferrite & cementite formed

$$M_\alpha = \frac{-1.15 + 6.67}{6.67 - 0.025} = 0.83$$

$(M_\alpha)_{Total} = 0.83 \times 1 = 0.83\,kg$

cementite formed $= m_{\beta} = m_{Fe_3C} = \frac{1.15 - 0.025}{6.67 - 0.025}$

$m_{Fe_3C} = 0.169$ kg

(iii) pearlite and proeutectoid phase formed.

1.15% 6.67.

$m_{pearlite}$ / ferrite side $(C < 0.8) = \frac{0.8 - 0.025}{1.15 - 0.025} = 0.68$ kg

$m_{pearlite}$ / $C > 0.8\% = \frac{1.15 - 0.8}{1.15 - 0.025} = 0.31$ kg.

$m_{Fe_3C\,(Pro)} = m_{Pro\,E\,(Fe_3C)} = \frac{1.15 - 0.025}{2.1 - 0.025}$

$m_{Pro\,E\,(Fe_3C)} = 0.5421$ kg.

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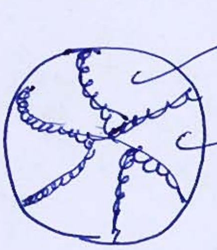
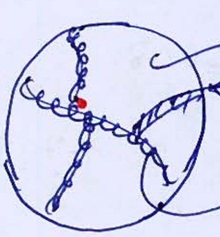
(iv) when (γ) just above the 727 °C the @ 1.15% wt C microstructure is



when cooled just below the 727 °C. the microstructure formed is.



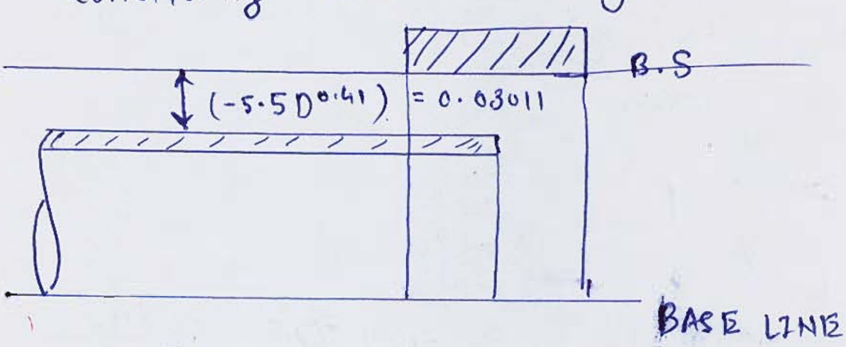
Q.6 (c) (i) Calculate the fundamental deviation and tolerance and hence the limits of size for shaft and hole for the following fit 65 H_8f_7 mm. The diameter steps are 50 mm and 80 mm. For the shaft designation f, upper deviation is assumed as $-5.5D^{0.41}$.

(ii) What is 3-2-1 principal of Location? What are the various degrees of freedom for body in space? Distinguish between a jig and a fixture.

[10 + 10 marks]

→ (i) Given data. 65 H_8f_7 50/80 mm.

Considering Hole basis System.



$i = 0.45\sqrt[3]{D} + 0.001D$ um.

— — $D_e = \sqrt{50 \times 80} = 63.2455$ mm

$i = 0.45\sqrt[3]{63.2455} + 0.001 = 1.7938$ um

$\varepsilon_f = -5.5 \times (63.2455)^{0.4}$

$\varepsilon_f = -30.115\ \mu m = 0.03115\ mm$

→ ~~Tolerance of shaft is 7i = 7×1.7938 = 12.5566 um = 0.0125 mm~~

→ Tolerance of hole is 8 = 25i = 25×1.7938
= 0.0448 mm

→ Tolerance of shaft is
= 16i = 16×1.7938
= 0.0287 mm

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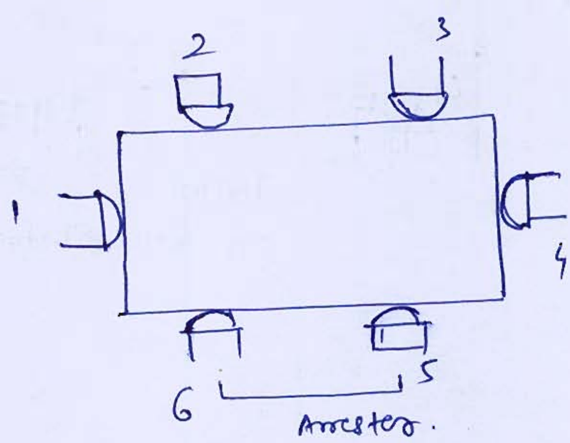
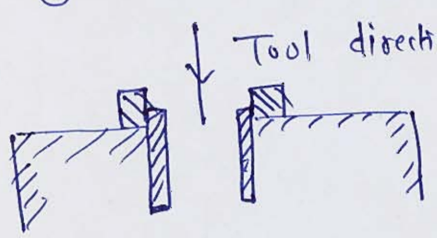
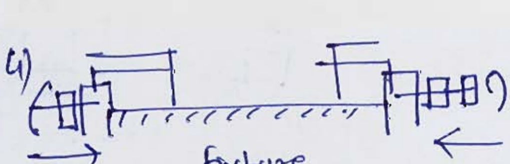
(ii) 3-2-1 Principal



→ using 6- different pin different degree of freedom can be obtained

→ Pin ① & ④ arrest the degree of freedom in longitudinal ie X (+ve) (−ve) dirn

→ Pin ② ③ and ⑥ ⑤ arrest free rotation in all three direction.

Jig	Fixture
1) Jig is used to locate ~~the~~ and guide the tool	1) fixture is used to locate the workpiece.
2) Jig is generally smaller in size	2) larger in size.
3) on jig plate multiple dimential jig can mount to guide the tool	3) only single defined workpiece can be mounted.
4) 	4) 

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(a) (i) Derive the relation for maximum uncut thickness in upmilling operation.

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

[8+12 marks]

(i)

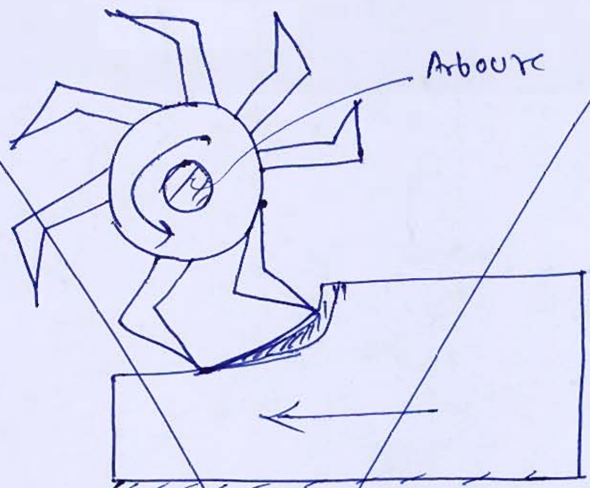

fig (Up Milling)

$$X_{max} = 2 f_t \sqrt{\frac{d}{D}\left(1-\frac{d}{D}\right)} \text{ mm}$$

$$X_{avg} = \frac{X_{max} + X_{min}}{2} \quad \because X_{min} = 0.$$

where as $f_t \rightarrow$ feed per tooth mm/tooth

$d \rightarrow$ depth of cut (mm)

$D \rightarrow$ diameter of milling (mm)

Struck off

(ii)

Q.7 (b) Explain stepper motor. Briefly discuss the working of the permanent magnet stepper motor with schematic diagram. Also write advantages and disadvantages of stepper motor.

[20 marks]

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Q.7 (c) Atomic radii; crystal structure, electronegativity, and the most common valency are tabulated in the following table for several elements; for those that are non-metals, only atomic radii are indicated.

Element	Atomic Radius (*nm*)	Crystal Structure	Electro-negativity	Valency
Cu	0.1278	FCC	1.9	+2
C	0.071			
H	0.046			
O	0.060			
Ag	0.1445	FCC	1.9	+1
Al	0.1431	FCC	1.5	+3
Co	0.1253	HCP	1.8	+2
Cr	0.1249	BCC	1.6	+3
Fe	0.1241	BCC	1.8	+2
Ni	0.1246	FCC	1.8	+2
Pd	0.1376	FCC	2.2	+2
Pt	0.1387	FCC	2.2	+2
Zn	0.1332	HCP	1.6	+2

Which of these elements would you expect to form the following with copper?

1. A substitutional solid solution having complete solubility.
2. A substitutional solid solution of incomplete solubility.
3. An interstinial solid solution.

[20 mark]

8 (a) (i) What is vulcanization process? What are its effect on the properties of rubber? Draw stress strain diagram for vulcanized and unvulcanized natural rubber.

(ii) Classify Nanomaterials and elaborate on one method of manufacturing carbon nano tubes (CNT).

[10 + 10 marks]

Q.8 (b) (i) Describe 'Degeneracy' and 'Dexterity' with respect to robots.

(ii) Calculate the inverse of following transformation matrix.

$$T = \begin{bmatrix} 0.527 & -0.574 & 0.628 & 2 \\ 0.369 & 0.819 & 0.439 & 5 \\ -0.766 & 0 & 0.643 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

[10 + 10 marks]

Q.8 (c) The following Taylor tool life equation for carbide tool, steel work piece pair is obtained experimentally: $VT^{0.25} = 650$ where V is in m/min and T is in min. A batch of 1000 steel parts, each 100 mm in diameter and 250 mm in length, is to be rough turned using a feed of 0.2 mm/rev. If the cost per edge of the throwaway carbide insert is ₹50, time required to reset the cutting edge is 1 min and the total machining cost (including operator cost) is ₹300/hr, calculate

1. optimum cutting speed for minimum cost
2. the corresponding tool life
3. total production cost if time taken to load and unload the component is 2 min, and the initial setup time is 2 hours, and
4. total production time for the given batch

[20 marks]

→ Given data: $VT^{0.25} = 650$, $f = 0.2$ mm/rev.

C_m = ₹ 300/hr.

Grind cost = ₹ 500/edge.

Reset = 1 min.

1.) optimum cutting speed @ minimum cost.

$\Rightarrow$ $T_o = \left(T_c + \frac{C_t}{C_m}\right)\left(\frac{1-n}{n}\right)$

$T_o = \left(1 + \frac{50 \times 60}{300}\right)\left(\frac{1-0.25}{0.25}\right)$

(2) $\boxed{T_o = 33 \text{ min.}}$ Ans.

2) from eqn $V_o = \frac{650}{(33)^{0.25}} = \underline{271.196 \text{ m/min}}$ Ans

3) C_p = Total production cost? $T_{unloading} = T_{setup} = 2 min$, $T_{isetup} = 2$ hours.

$C_t \rightarrow$ tooling cost

$C_p = C_m + C_t + C_s + C_l$

$= \frac{\pi D L}{1000 V} \times \frac{300}{60} + \frac{50}{T_o} \times T_m + (2 + 120) \times T_m$

$= \frac{\pi \times 100 \times 2500}{1000 \times 271.196} \times \frac{300}{60} + 50 \times \frac{0.2896}{33} + 122 \times 0.2896$ 0.2896.

$= 1.448 + 35.769 \Rightarrow \boxed{C_p = ₹ 37.217}$

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(4) Total Production time.

$(T_p)_{time} = T_m + \frac{T_o}{T_m} \times 1000$

= ~~1000 × 0.2896~~ + ~~@~~

$= 1000\left(0.286 + \frac{0.2896}{33} + 2\right)$

$\boxed{T = 2286 \text{ min}}$ Ans = 2~~294.67~~ min.

0000

$A_s =$

$\left(\frac{A}{V}\right)$ $\frac{2 \frac{\pi}{4} \times D^2 + \frac{\pi}{4} D^2 \, \pi D H}{\frac{\pi}{4} \times D^2 H}$

$\frac{2}{H} + \frac{4 \pi D H}{\pi D^2 H}$ $d\left(\frac{2}{D/4} + \frac{1}{D^2}\right)$

$\frac{2}{D} + \frac{4}{D^2}$

Space for Rough Work

Space for Rough Work