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17ME82

Eighth Semester B.E. Degree Examination, July/August 2022
Additive Manufacturing

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define Additive Manufacturing. List out advantages and disadvantages in detail. **(10 Marks)**
b. Explain the process chain of Additive Manufacturing. **(10 Marks)**

OR

2 a. Explain Molten Material System (Fused Deposition Modelling (FDM) in Additive Manufacturing with a neat sketch. **(10 Marks)**
b. Explain post processing of Additive Manufacturing. **(10 Marks)**

Module-2

3 a. Classify hydraulic motor and explain with a neat sketch Gear Motor. **(10 Marks)**
b. Write short notes on:
(i) Relays
(ii) Solenoids **(10 Marks)**

OR

4 a. With a neat sketch, explain the construction of single acting and double acting hydraulic cylinders. **(10 Marks)**
b. Write short notes on :
(i) Piezoelectric actuators
(ii) Shape memory alloys **(10 Marks)**

Module-3

5 a. Classify polymers and explain melt spinning process in detail. **(10 Marks)**
b. Briefly explain steps in powder metallurgy. List advantages, disadvantages and applications. **(10 Marks)**

OR

6 a. Sketch and explain dry spinning process. **(10 Marks)**
b. Define atomization. Explain Gas Automization and Water Automization with sketches. **(10 Marks)**

Module-4

7 a. Explain bottom-up and top-down approaches. **(10 Marks)**
b. Explain Scanning Electron Microscope, with a neat sketch. **(10 Marks)**

OR

8 a. Explain X-ray Powder Diffraction (XPD) in Additive Manufacturing. List advantages, disadvantages and applications. **(10 Marks)**
b. Explain Scanning Probe Microscope (SPM) with a neat sketch. Also list advantages and disadvantages of SPM. **(10 Marks)**

Module-5

9 a. Differentiate between Computer Numerical Control (CNC) and Direct Numerical Control (DNC) System. **(10 Marks)**

b. Define Automation. Explain with a block diagram different levels of automation. **(10 Marks)**

OR

10 a. List the advantages and disadvantages of CNC machines. **(10 Marks)**

b. Write a manual part program for machining the profile shown in Fig.Q10(b). (All dimensions are in mm)

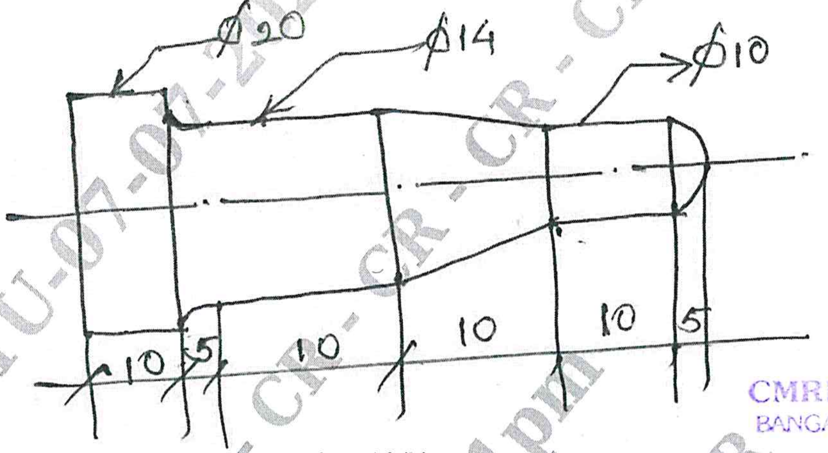

Fig.Q10(b) **(10 Marks)**

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21/05/2021

Additive Manufacturing:

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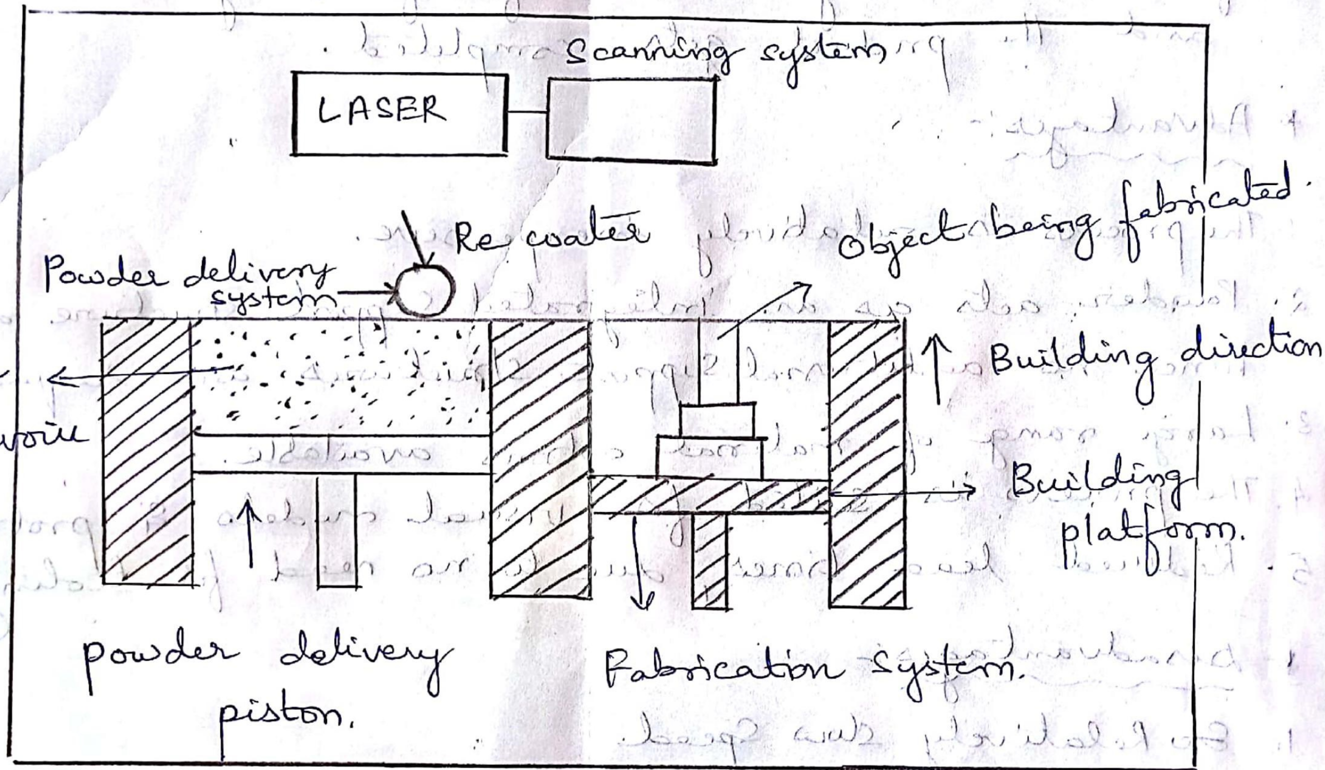
(5) Selective Laser Melting process.

* Schematic diagram:-



Enclosed chamber filled with Argon gas.

→ Selective Laser melting (SLM) machine has a a chamber filled with metal powder. This metal powder is then spread across the substrate or build plate in very thin layers by a coater blade.

→ A high power laser fuses the 2D slice of the part by selectively melting the powdered material. The building platform then drops down by the height of one layer, the coater spreads another layer of fresh powder finely across the surface.

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→ This process is repeated until the part is completly finished

→ Once the object is built, it is removed from the building platform and the supports are removed

→ further machining and Surface finishing is done and the product gets completed.

* Advantages :-

1. The process is relatively inexpensive.
2. Powder acts as an integrated support structure and hence no additional support structures are required.
3. Large range of material options available.
4. The process is suited for visual models & prototypes
5. Reduced lead times, due to no need for tooling

* Disadvantages :-

1. Ex Relatively slow speed.
2. Lack of structural properties in materials.
3. process has high size limitations.
4. High power usage.

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(03) Applications of Additive Manufacturing:

Industry is taking advantage of aditive manufacturing to produce plastic, metal, or composite parts and custom products without cost, time, tooling and overhead required in traditional machining or manufacturing processes.

→ Aerospace Industry is taking advantage of AM to simultaneously reduce material requirements and easily create engine parts.

→ Many military operations also require miniaturized, custom designed components in relatively small numbers.

→ For automotive industry, additive manufacturing holds great promise. Vehicle bodies and engines could be made using fewer parts and rapidly redesigned to minimize failures.

→ Health care industry is investing in tailored prosthetics dental implants, hearing aids, and other medical devices and tools.

→ They give industry new design flexibility, reduce energy use and shorten time to market.

→ Manufacturers of many consumer products may soon be using additive techniques to improve electrical performance and reduce weight and volume.

→ Additive manufacturing is used for aesthetic purposes such as for design, show case items, gifts and also statues etc.

→ It is also used in food industry and other various industries for producing vessels and cookeries.

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⑥ Post processing techniques.

Most AM processes require post processing after building to prepare the part for its intended use.

1. Support material removal :-

Support material can be classified as (a) material which surrounds the part as a naturally occurring by product.

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(b) rigid structures which are designed and built to support, restrain or attach the part being built. This has to be removed.

(ii) Surface Texture improvements :-

AM parts have common surface texture featu-res that may need to be modified for aesthetic or performance reasons. Common surface textures are :- Stair steps, powder adhesion, fill patterns from extrusion or beam based systems, witness marks from support material removal.

The type of post processing utilized for surface texture improvements is dependent upon the desired surface finish outcome.

If a smooth or polished surface desired, then wet or dry sanding and hand polishing performed.

(iii) Accuracy Improvements :-

There is a wide range of accuracy capabilities in AM. Process dependent errors affect the accuracy of the part. These errors come from positioning and indexing limitations.

Repeatable shringking and distortion can be compens-ated for by scaling the CAD model.

Preprocessing of STL file to compensate for inaccura-cies followed by finish machining of final part.

(iv) Aesthetic Improvements :-

Aesthetic improvements such as painting, surface finishing and polishing increases the quality and look of the material. ICR17ME056

Another Aesthetic enhancement is chrome plating through electrolysis process: to enhance the properties and look of the material.

5(V) Preparation for use as a pattern.

often parts using AM are intended as patterns for investment casting, sand casting, room temperature vulcanizations, and other pattern replication process. The accuracy and surface finish of AM pattern will directly influence the final part accuracy and surface finish. As a result special care must be taken to ensure pattern as accuracy and surface finish as the final part.

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(01) Additive manufacturing is a process by which digital 3D design data is used to build up a component in layers by depositing material. It is also called as 3D printing, rapid prototyping layer fabrication etc..

* Steps involved in AM process:-

1. Conceptualization and CAD.

All AM parts must start from a software model that fully describes the external geometry. This can involve the use of almost any CAD solid modelling software, but output must be 3D solid or surface representation.

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2. Conversion to STL

Nearly every AM machine accepts the STL file format. This file describes the external closed surfaces of original CAD model and forms the basis for calculation of the slices.

3. Transfer to AM machine and STL file manipulation

The STL file describing the part must be transferred to AM machine. Here there may be some general manipulation of the file so that it is correct size, position and orientation.

4. Machine setup :- The AM machine must be properly set up prior to the build process. Such settings could relate to the build parameters like material constraints, timings etc

5. Build :- Building the part is mainly an automated process and the machine can largely carry on without supervision.

6. Removal :- Once the AM machine has completed the build, parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure for operating temperatures

7. Post processing :- Once removed from machine, parts require cleaning and processing before use.

8. Application :- Parts may be now ready to use. However they may require additional finishing for aesthetic reasons. (painting etc).

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② Various challenges faced by additional manufacturing processes:-

(a) Technological challenges:-

(i) Slow production speeds

(ii) Material development and inconsistencies in material preparation.

(iii) Manual post processing.

(b) Software challenges.

(i) Limited capabilities in data preparation and design

(ii) Quality assurance challenges.

(iii) Part to part variation.

(iv) Lack of industry-wide standards.

(c) Workforce challenges.

(i) Lack of understanding and expertise in additive manufacturing

(d) Financial challenges

(i) initial investments

(ii) maintanance and repair charges.

(iii) Operation charges and electricity charges

(iv) Use of expensive materials and gases for manufacture.

e) Workflow and integration challenges:-

(i) Disjointed Additive manufacturing ceo systems

(ii) Lack of digital infrastructure.

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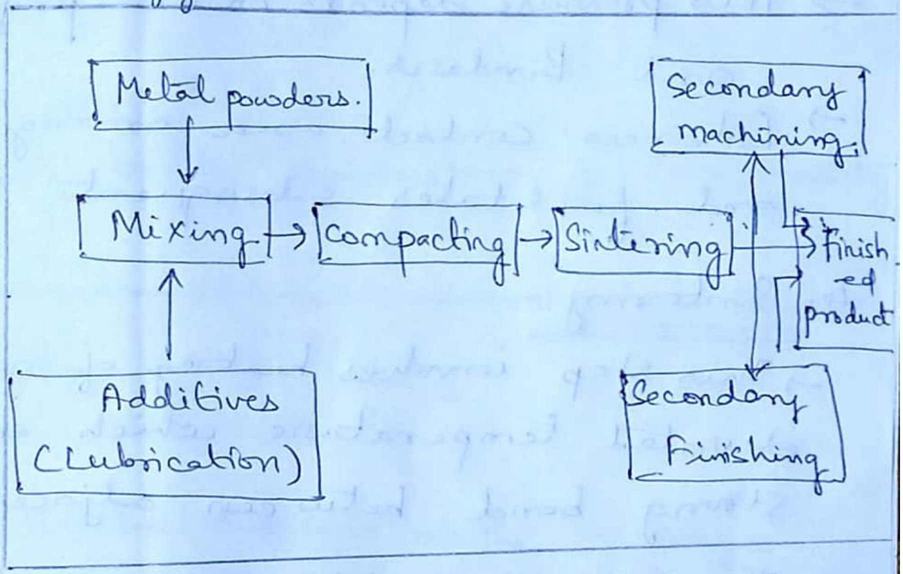
19/06/2021 Internal Assessment - II.

Additive Manufacturing

① Powder metallurgy can be defined as the process of preparation and process the powdered iron or non-ferrous metals or materials.

The steps in powder metallurgy are:-

1. Powder preparation
2. Mixing and Blending
3. Compacting.
4. Sintering.
5. Secondary operations.



Diagrammatic representation.

1. Powder preparation:-

→ First and Basic step in powder metallurgy. Any material can be converted into powder

→ There are various process of producing powder such as atomization, grinding, chemical reaction, ball milling, Electrolysis etc...

2. Mixing and Blending:-

→ Blending imparts uniformity in the shapes of the powder particles

→ Process ensures even distribution of powder with additives binders etc

→ Lubricants are added to improve flow characteristic of powder.

3. Compacting:-

→ Compacting means compressing the prepared powder mixture into predefined dies

→ This step ensures to reduce the voids and increase the density of the product.

→ It involves pressure range from 80 to 1600 MPa

→ This pressure depends on the properties of metal powder and Binders.

→ Enhances contact area among the powder particles and facilitates subsequent sintering process.

4. Sintering:-

→ This step involves heating of green compact at an elevated temperature which ensures a permanent strong bond between adjacent particles.

→ This process provides strength to green compact & converts to final product

→ The sintering temperature is about 70-90% of melting temperature of metal powder

5. Secondary operations.

→ Sintered object is more porous compared to full dense material.

→ Some finishing operation such as repressing, sizing, hot forging, infiltration is done to further improve the quality of the product.

→ Most common secondary operation are sizing, coining, impregnation, hot forging etc.

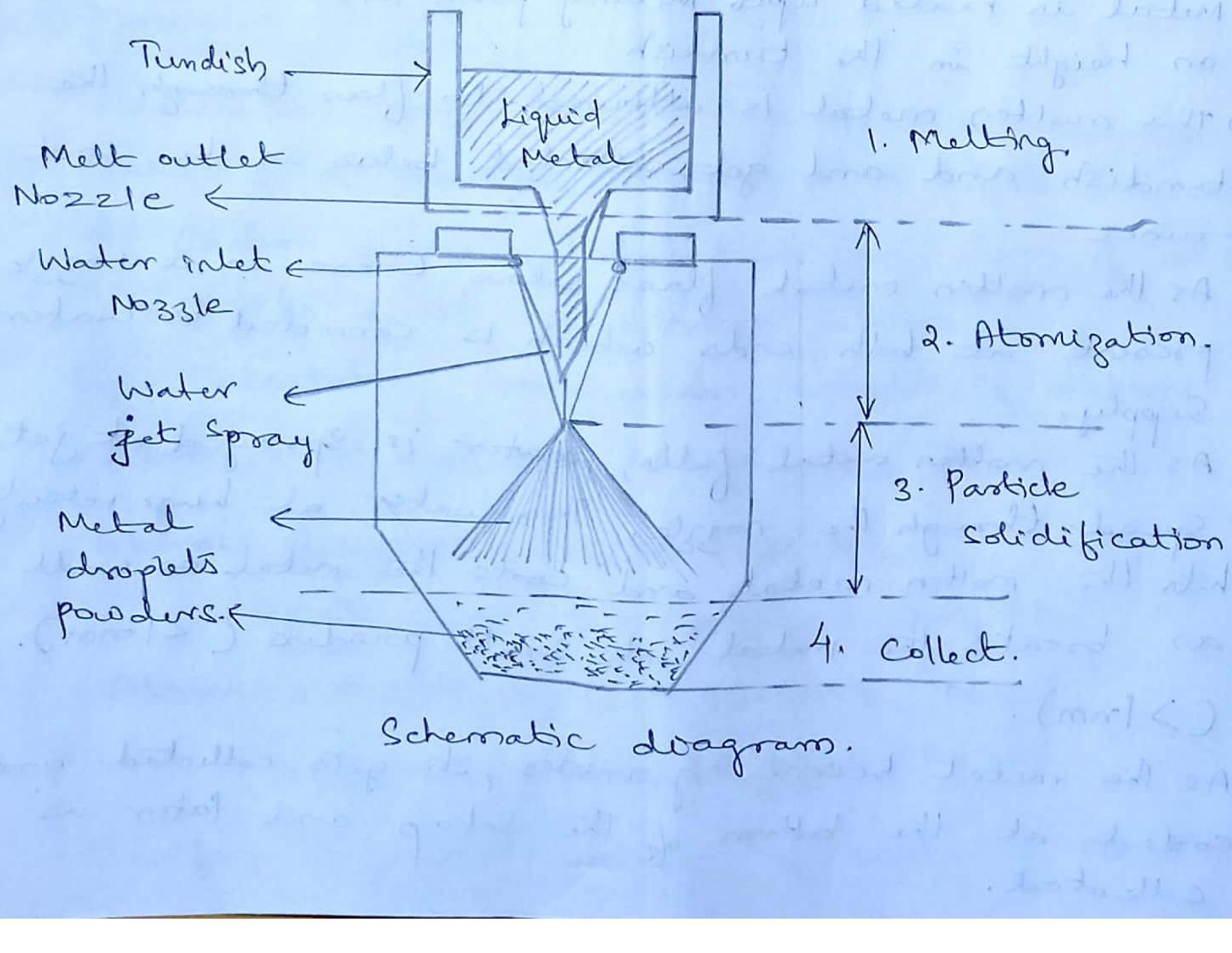
* Advantages :-

1. High production rate can be achieved
2. Machining operation is eliminated
3. Reduced production time

* Disadvantages :-

1. High initial cost of metal powder
2. High tooling cost
3. Equipments used are costly. and poor plastic properties

② Water Atomization process.



Schematic diagram.

* Water atomization of metals is process done inorder to achieve fine particle distribution for a range of materials.

→ **Construction :-**

a) Metal powder is heating upto its melting point and molten metal is placed inside the tundish.

b) There are water jet sprayers inorder to facilitate atomization

c) It consists of a collecting dish below inorder to collect the fine powder particles of the metal

→ **Working :-**

→ Metal is heated upto melting point and stored at an height in the tundish.

→ This molten metal is allowed to flow through the tundish and and get collected below in the container

→ As the molten metal flows below, there is a nozzle present at both ends which is connected to water supply.

→ As the molten metal falls, water is sprayed at jet speed through the nozzle. This water at huge velocity hits the molten metal and cools the metal as well as breaks the metal into small powders (<1mm). (>1mm).

→ As the metal becomes granules, it gets collected and cooled at the bottom of the setup and later is collected.

* Advantages :-

1. It is a short process with high production efficiency
2. Suitable for large scale production
3. Cheap raw materials can be used to produce high value and high quality powder

* Disadvantages :-

1. Initial investment is very high.
2. It is not conducive to the production of low density iron powder.

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(4) Explain the following :-

(a) Molecular Weight.

Molecular weight can be defined as the average mass of a molecule compared to 1/12th the mass of Carbon 12 and calculated as the sum of atomic weights of the constituent atoms.

Eg :- Calculating molecular weight of water.

Atom :- H and O, molecule (H_2O).

Atomic weight of H. ⇒ 1.00794.

Total mass = 2 × 1.00974 = 2.01588.

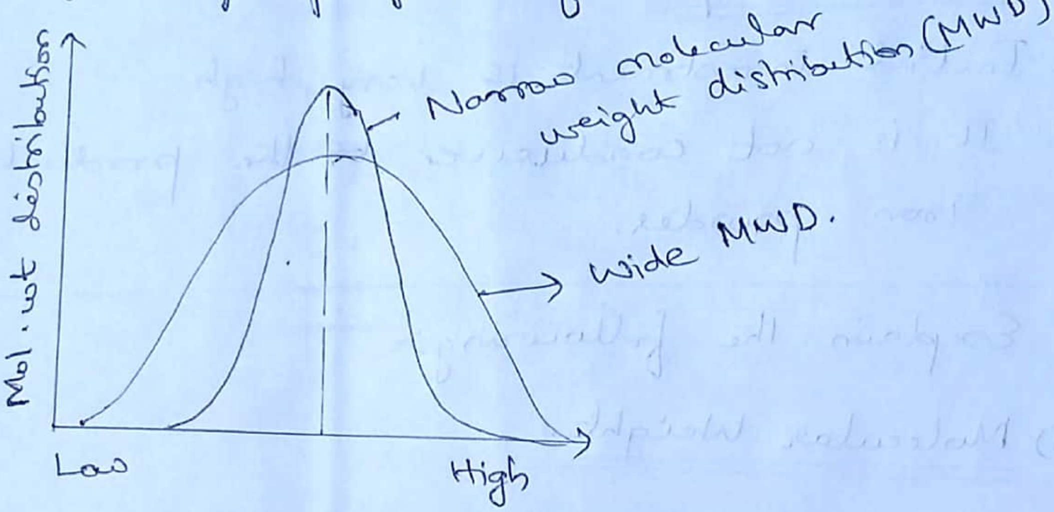
Atomic weight of O ⇒ 15.9994. ≈ 16.

Total weight = 18.0153 ≈ 18.

Therefore molecular weight of water = 18.0153 g/mo

(b) Weight molecular distribution.

The molecular weight distribution describes the relationship b/w number of moles of each polymer species (N_i) and molar mass (M_i) of that species. The molar mass distribution of polymer may be modified by polymer fractionation.



(C) Particle size:- Particle size is a term used to compare solid, liquid and gas dimensions. This can be applied to ecology particles, granular material particles and colloidal particles

An object with spherical size can be defined through its diameter. However a common non-spherical object particle size can be based on volume, area and weight.

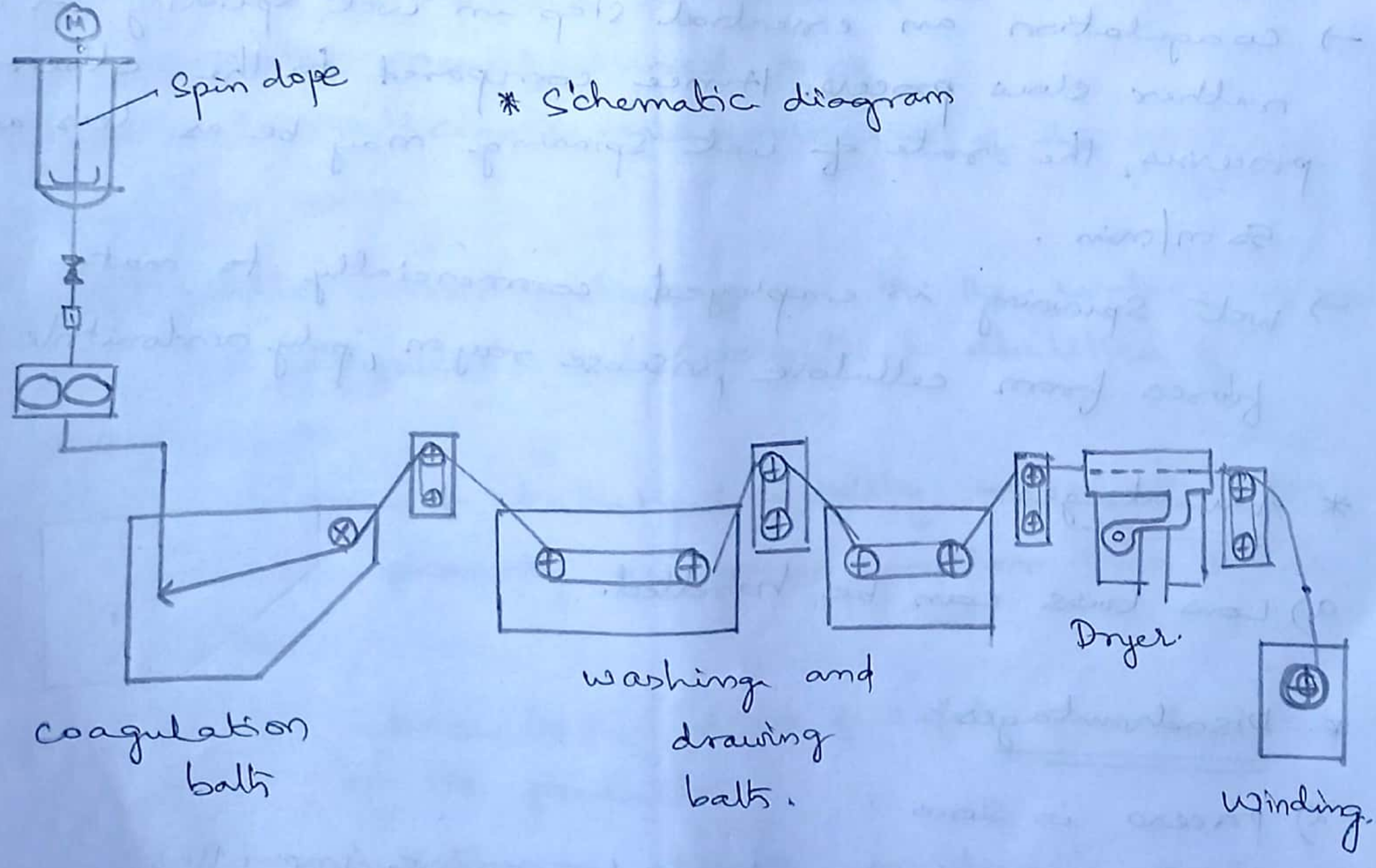
(d) Particle shape:- Particle shape is defined by the relative dimensions of the long, intermediate, and short axes of a particle. It is the external apperance of a particle. Various different aspects of particle

shape are of interest and range of descriptors has (7)
been devised to allow particle shape to be described.

(c) Powder Structure :- A powder is a dry, bulk solid composed of many very fine particles that may flow freely when tilted or shaken. Powders are special sub class of granular materials. Powders are very fine and Homogenous in nature.
Many powder behaviours are common to all granular materials. These include segregation, stratification, jamming and unjamming, shearing and fragility.

(3) Wet Spinning method.

* Schematic diagram



Wet spinning employs fairly concentrated polymer
→ solution. The process details for wet spinning also converts a viscous polymer solution into fine jets through spinner.

→ These jets are led into coagulation baths containing large volume of non solvent which can precipitate the polymer from its solution.

→ When continous jets of polymer solution come in contact with a non-solvent, they precipitate in the fine elements.

→ Filaments are gathered on a spindle after undergoing washing, drying etc...

→ coagulation an essential step in wet spinning is a rather slow process. Hence compared to the other processes, the rate of wet spinning may be as less as 50 m/min.

→ wet spinning is employed commercially to make fibres from cellulose, viscose rayon, poly acrylonitrile etc.

* Advantages:-

a) Low tows can be handled.

* Disadvantages:-

a) process is slow.
b) Washing is to be done to remove impurities
c) solvent and chemical recovery.

(5) Defects analysis of sintered components.

(a) Testing and inspection procedures which donot realistically reflect actual use situation, eg:- particle size yeild in floor screening by vibro screens. vs the laboratory routine screening.

(b) Arbitrary material substitution by the purchasing or manufacturing departments, without adequate engineer-ing evaluation.

(c) crash design to incorporate new feautures in existing designs with minimum tooling changes.

(d) Failure apply the same evaluation methods to purchased components or powders as are applied to internally manufactured ones

(e) Failure to anticipate misapplication of the product by the user

(f) Too little consideration given to the wide variation in the physical and intellectual abilities of customers

(g) Interpretation of statistical quality control function as absolute quantity assurance rather than basis for action

(h) Inadequate advice to the user of safety procedures related to the product

(i) The powder metallurgy allows considerable cost variation if specific part requirements are not clear.

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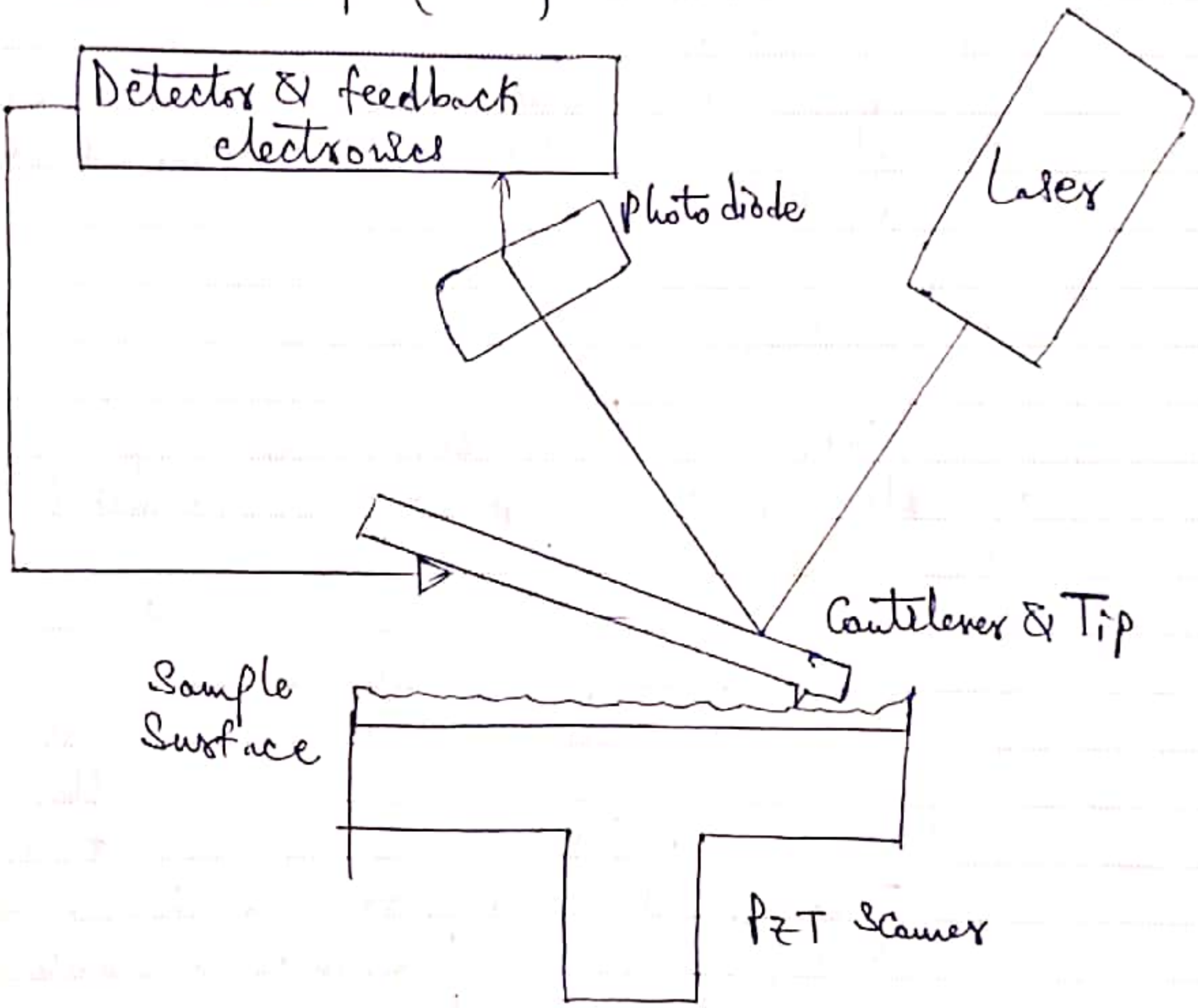
(6)
1)

Scanning Probe Microscope (SPM):



→ Scanning probe microscope several related technologies for imaging and measuring surfaces on the fine scale, down to the level of Molecules & grouping of Atoms.

→ SPM are very powerful family of microscope and can detect differences in height that are a fraction of Nanometer.

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* **Principle:-**

An SPM has a probe Mounted on the end of Cantilever. The tip Can be as sharp as single atom. It Can be moved precisely & accurately across the Surface.

SPMs Can measure deflections Caused by Mechanical Contact, electrostatic force, Chemical bonding etc.

* **Working:-**

SPM technologies share the Concept of Scanning an extremely sharp tip (3-50nm radius of Curvature). across the object surface.

The tip is Mounted on a flexible Cantilever allowing the tip to follow surface profile.

When the tip moves in proximity to the investigated object, force of interaction b/w the tip and the Surface influence the Movement of Cantilever.

The tip is moved across the Sample many times. A Computer Combines the data to Create an Image.

Scientists use SPMs in different ways,

(i) Contact Mode → force b/w tip & Surface is Constant.

(ii) Tapping Mode → the Cantilever oscillates, intermittently touching the Surface.

* Advantages of SPM:

It provides observation of large variety of specimen using same microscope.
Reduces the time required to prepare & study specimen.
These are faster, more efficient with minor effort & Modification.

* DisAdvantages of SPM:

Images are black & white.
Slow in acquiring images.
The Max. image size.

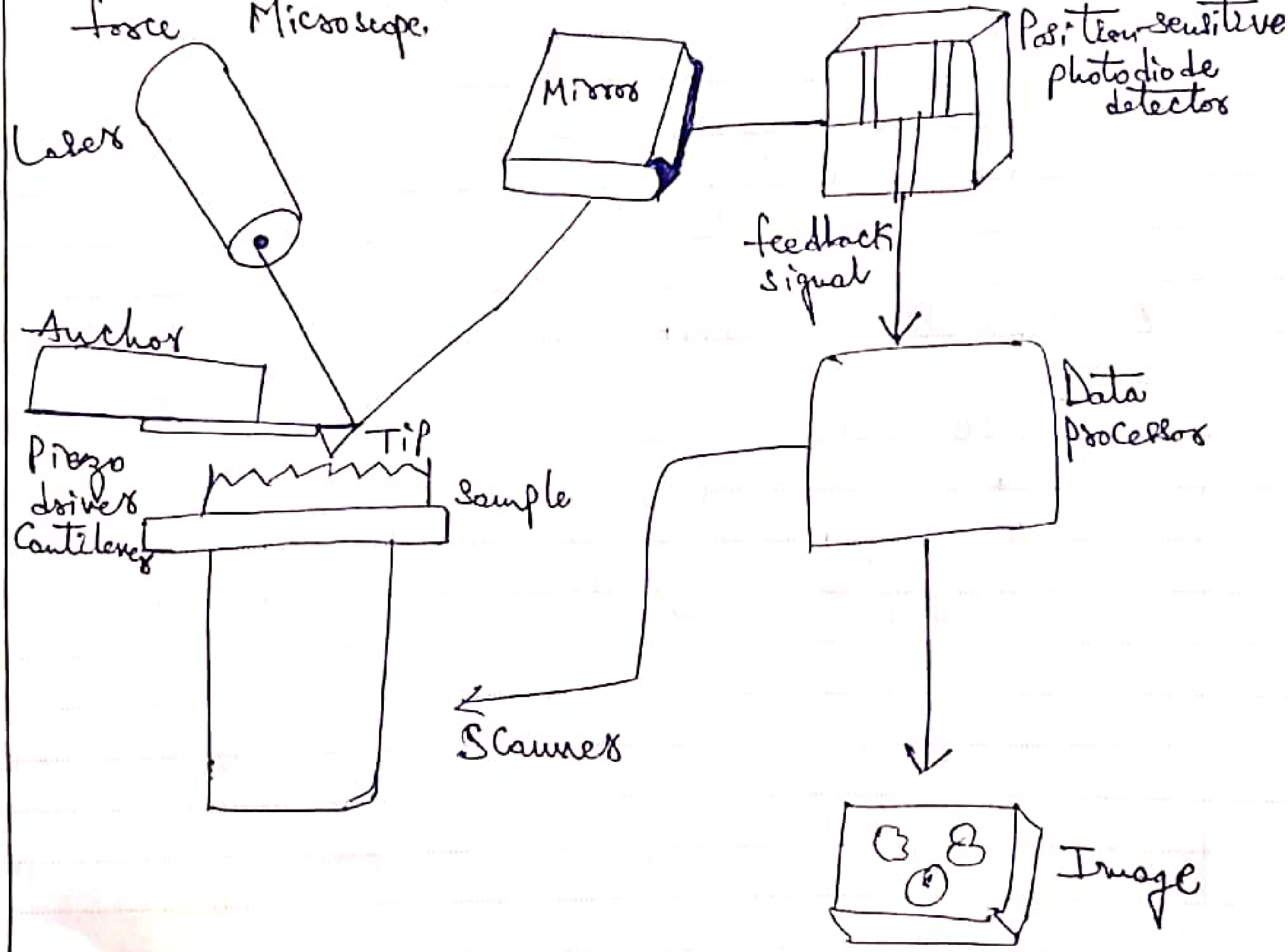
* Applications of SPM:

DNA imaging
Nano Lithography
Measuring physical & chemical surface
Imaging of polymers.

2)

Atomic force Microscope

→ It is a very high-resolution type of scanning probe microscope that can work more than 1000 times better than the optical diffraction limit and can imaging, measuring and manipulating matter at Nano Scale. It can also be called as "Scanning force Microscope."



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It Consists of :-

* Laser
* Photodiode
* Cantilever with Sharp tip
* Detector & feedback Circuit
* Piezoelectric Scanner.

Working:-

* AFM Consists of Microscope Cantilever with a sharp tip at its end and is used to Scan the Surface of a Specimen.
* The Cantilever is typically Silicon / silicon Nitride with the tip radius of Curvature of the order of "nm".

Basically, when the tip is brought Close to the Sample, force b/w the tip ~~is brought close to~~ & Sample leads to deflection of Cantilever according to "Hooks Law".

Instead of electrical signal, the AFM relies on forces b/w the atom in the tip & in the sample.

* The force present is kept Constant and the Scanning is done. As the Scanning Continues, the tip still have Vertical movements depending upon the topography of the Sample. The force present is kept Constant.
* A Laser is used to record the Vertical movement of Needle. This information is later Converted into Visible from using photodiode

Depending upon the Situation, AFM measures different types of forces.

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* Advantages:-

Easy sample preperation.
Works in Vaccum, Air & Liquids.
Accurate height information.
Living system can be studied
3D Imaging.
Surface roughness quantification.

* DisAdvantages:-

Limited Vertical range.
Limited Magnification range.
Tip (or) sample can be damaged
Limited scanning speed

* Applications:-

Semiconductor Science & technology.
Thin film & Coatings.
Cell biology.
Molecular biology.
Triology.

(5)

1)

Wet Chemical Synthesis of NanoMaterials

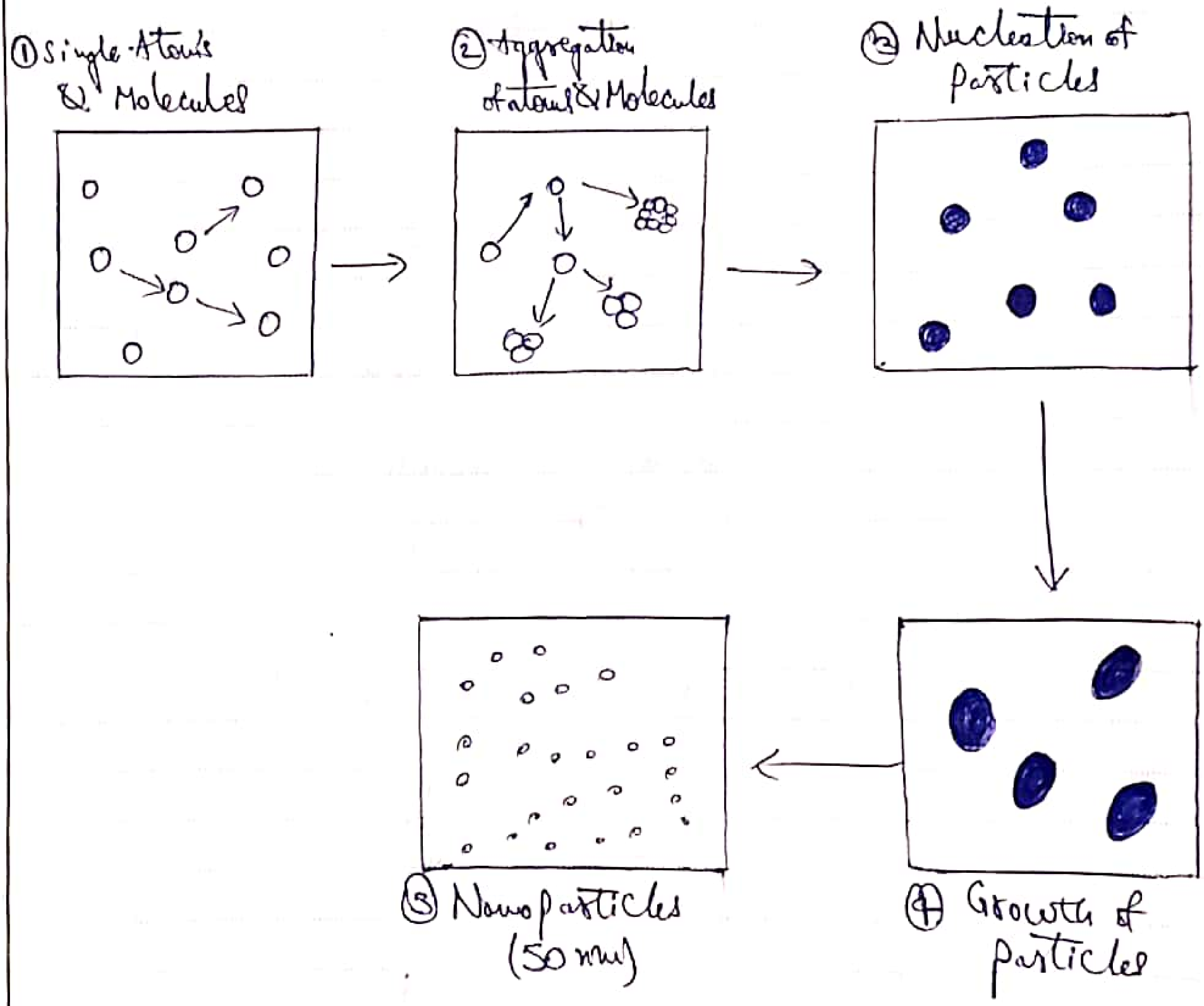
* This is a bottom up approach for the Synthesis of Nanomaterials. It includes percipitation of solids from a Supersaturated Solution, Homogeneous liquid phase, chemical reduction & Ultrasonic decomposition of Chemical precursors.
* This process are attractive due to their simplicity, Versatility & availability of low Cost precursors.
* A typical example is the formation of Nano-Crystalline titania powders via Hydrolysis of $TiCl_4$ at low temp.

$$TiCl_4 + 2H_2O \longrightarrow TiO_2 + 4HCl.$$

* Once the Solution becomes Saturated, Crystallization of titania takes place either Homogeneous (or) Heterogeneous Nucleation.

* Metal Nanoparticles Can also be generated through Ultrasonic & thermal decomposition of metal Salts & Chemical precursors (~ 3000K) & High pressure (~1000 Atm).

* The Main event in this process is Nucleation, growth & Collapse of Cavitation bubbles formed in the liquid.



Wet Chemical Synthesis of Nano particles.

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2)

Sol-Gel Process:

* Solgel process is also Called as "Wet Chemical Synthesis". It is a process of Bottom up approach, where microscopic particles are Converted to macroscopic particles.

* The Substances (or) Chemicals involved in the Solgel process is in Wet Condition.

* During the preparation of Nanomaterials, the "Sol" (Colloiding Suspension) is Converted to "gel".

* This method is used for preparing Nano-Sized Metal oxide.

* The precursor used to prepare Nano-sized Metal oxide is Metal-Alkoxide.

* The Metal-Alkoxide is mixed with water (H_2O) Because H_2O acts as a Catalyst.

* Initially Metal-Alkoxide wont be Soluble in water, Hence, Alcohol is added. Once dissolution occurs, then the dissolved Substances is mixed with water.

* The precursor undergoes Continuous Stirring and results in Hydrolysis.

* As a result of Hydrolysis, sol is formed (Sol is a Metal Hydroxide, which is not Soluble in H_2O, Hence it is Called Colloidal Suspension of M-OH in H_2O.

* The sol is undisturbed for days, due to which aging results, Because some of the water Molecule evaporates, this phenomenon is Called "Condensation".

* During Condensation process M-O-M bond is formed. where M → Metal, O → Oxygen. In this process, polymerisation of M-O-M bond generates which in turn Nanomaterial Metal-oxide is formed

* Next step is extraction, and undergoes following process.

* During drying of gel, Solvent molecules (alcohol) associated with Nanopractise is eliminated.

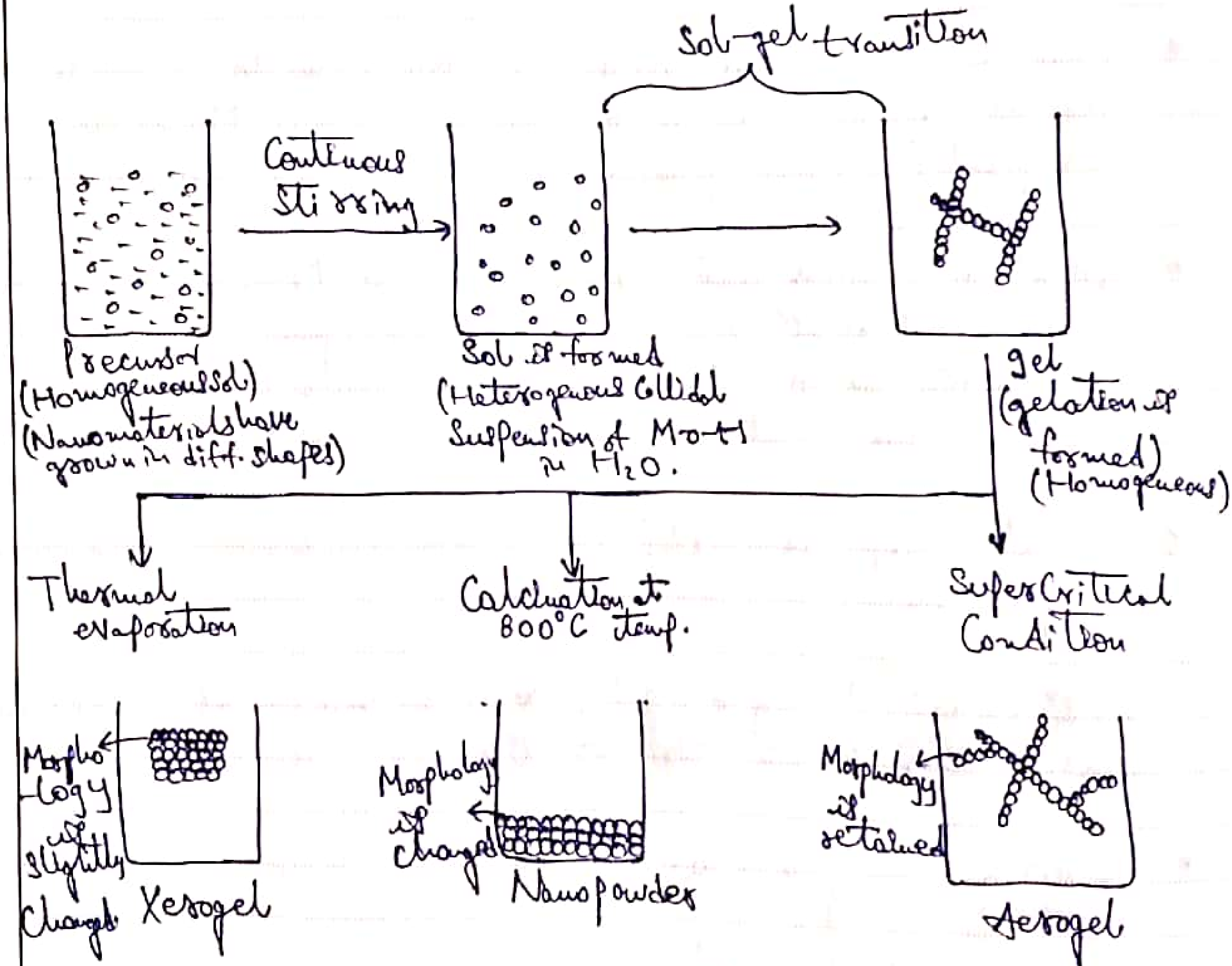
* Drying of gel Can be done in three ways.

1) Supercritical Condition,
2) Calcination at >800°C
3) Thermal evaporation.

* Chemical reactions involved:

$$\underset{\text{Sol}}{\underbrace{M-OR + H_2O \rightarrow MOH}} + ROH \quad \text{(Hydrolysis)}.$$

$$MOH + ROM \rightarrow \underset{\text{gel}}{\underbrace{M-O-M}} + ROH \quad \text{(Condensation)}.$$



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②

CNC (Computer Numerical Control) Machining is a Manufacturing process in which pre-programmed Computer Software dictates the movement of factory tools & machinery. The process can be used to control grinders & lathes to mills etc...

* Components of CNC Machine tool System:

a) Central Processing Unit (CPU):

The CPU is the heart of a CNC system. It accepts the information stored in the memory as part program. This data is decoded and transformed into specific position control & Velocity signals.

b) Servo Control Unit:

The position & Velocity control signals, generated by the CPU forms the inputs to the servo control unit. This unit generates suitable signals that are converted by the servo drive, which are interfaced with the axes & spindle motors.

c) Machine Control Panel:

It is the direct interface b/w the operation and the NC System, enabling the operation of machine

During program execution, the CNC controls the axis of the motion spindle function depending on the program.

d) Operator Control panel:-

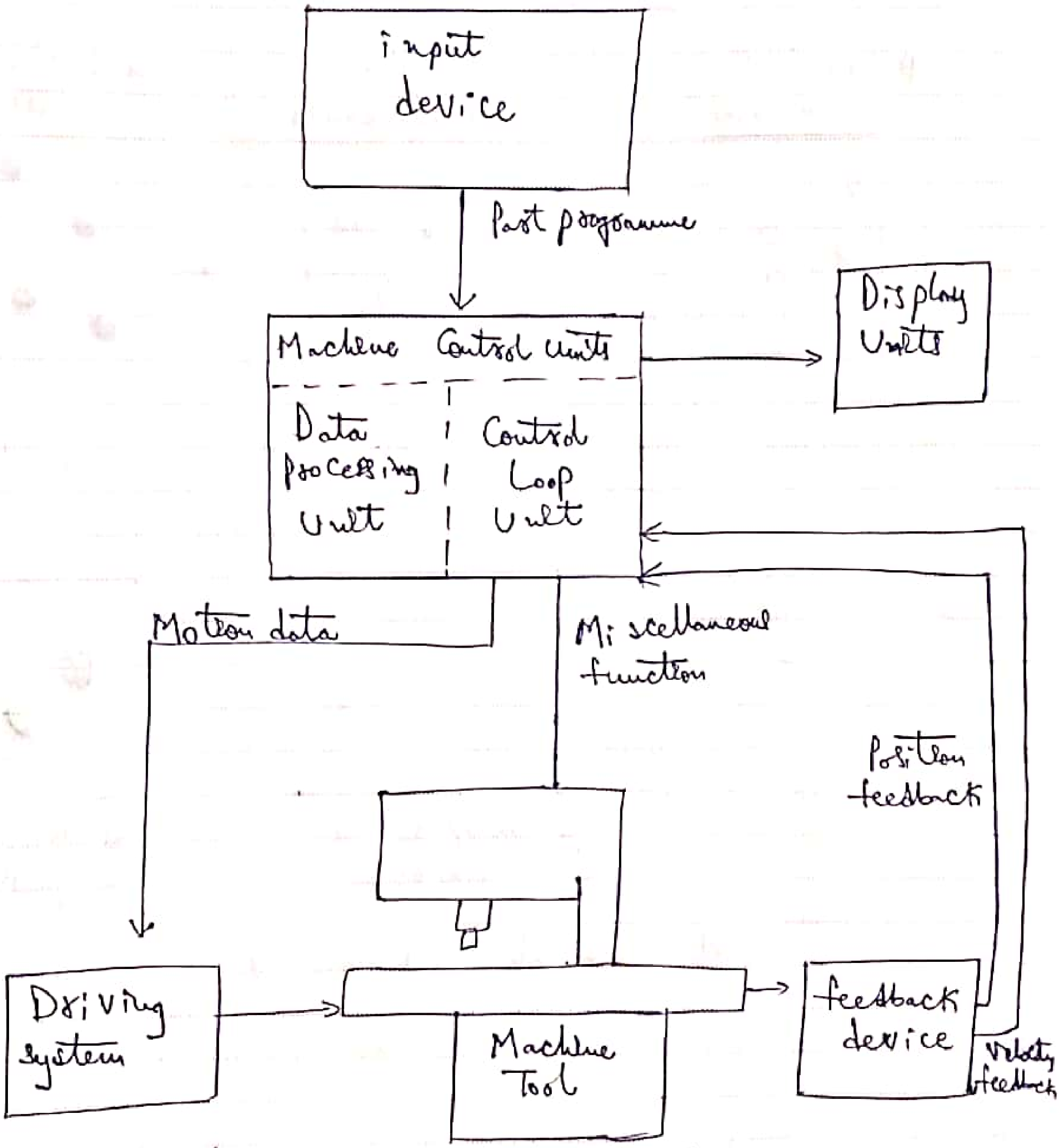
The operator control panel provides two way communication b/w users, CNC system & the M/c tool.

e) Programmable Logic Control (PLC):-

A PLC matches the NC to the Machine. These are developed to be re-programmed without Hardware changes when requirements were altered. PLCs are now available with increased functional, more memory etc--

f) other Peripheral Devices:-

These include sensor interface, provision for communication equipment, programming units, printer etc--



Block dia of CNC Machine

1) a)

Manual Part Programming :

→ To prepare a part program using the manual method, the programmer writes the machine instructions on a special form called "Part programming Manuscript".

→ The instruction must be prepared in a very precise manner because the typist prepares the NC tape directly from the Manuscript.

→ The Manuscript is a list of relative tool & W/P, Locations. It includes other data, such as preparatory Commands, Miscellaneous instructions etc.

→ Manual programming jobs can be divided into two categories, point to point jobs & Countouring jobs.

→ Expect for Complex work parts with many holes to be drilled, manual programming is ideally suited point to point applications.

→ On the other hand, except for the simplest milling & turning jobs, Manual programming can become quite time consuming for applications requiring contour path control of the tool.

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→ Accordingly, we shall be Concerned only with manual part programming for point operations.

NC Words are:

* Sequence Number (N-Word)
* Preperatory functions (G-Word)
* Co-ordinates (X, Y & Z Words)
* Feed function (F-Word)
* Spindle Speed function (S-Word)
* Tool Selection function (T-Word)
* Miscellaneous function (M-Word)
* End of block (EOB).

b)

Computer assisted part programming:

→ In the more Complicated point to point jobs and in Contouring applications Manual part programming becomes an extremely tedious task and Subject to errors.

→ In these instances, it is much more appropriate to employ the High speed digital Computer to assist in the part programming process.

→ The Part Programmer's job:

* Defining the work part geometry.
* Specifying the operation sequence & tool path.

→ Defining the work part Geometry:

No matter how complicated the workpart may appear, it is composed of basic geometric elements. Although somewhat irregular in over all appearances.

→ Specifying the operation sequence & the Tool path:

* This Tool path specification involves a detailed step by step of cutter moves.
* In addition part surfaces to go point location.

→ The Computers Job:

* input translation
* Arithmatic Calculations
* Cutter offset Computation
* post processor.

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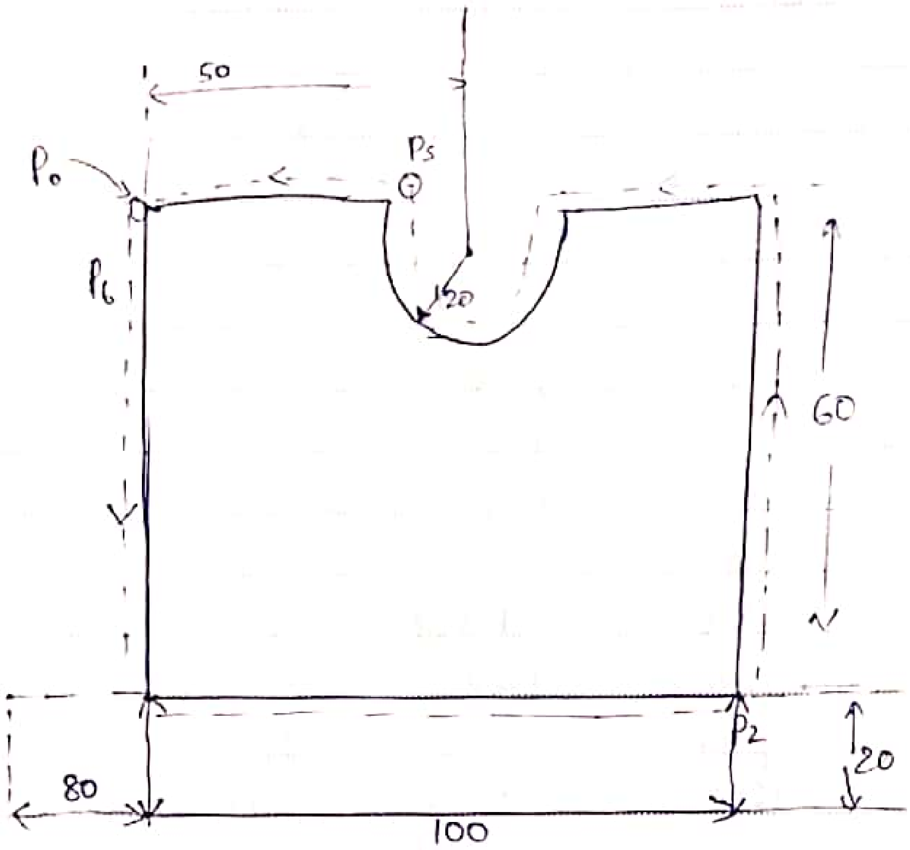
③



Absolute

Sl No	X	Y
1	80	20
2	180	20
3	180	80
4	130	80
5	110	80

	X	Y
6	80	80
7	80	20

[Billet X200 Y200 Z10

[Tool Def T01 D5]

[EDGE M001 X0 Y0]

N01	G21	G94		
N02	G91	G28	Z0	
N03	G28	X0	Y0	
N04	M06	T01		
N05	M03	S1000		
N06	G90	G00	X80	Y20
N07	G01	Z-10	F50	
N08	G01	X180	Y20	
N09	G01	X180	Y80	
N010	G01	X130	Y80	
N11	G02	X110	Y80	
N12	G01	X80	Y80	
N13	G01	X80	Y20	
N14	G01	Z-10		
N15	G00	X0	Y0	
N16	M05	M30		