**CBCS SCHEME**

USN | | | | | | | | | | |

**BME405A**

# Fourth Semester B.E./B.Tech. Degree Examination, June/July 2024
## Non Traditional Machining

Time: 3 hrs. Max. Marks: 100

***Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.***
***2. M : Marks , L: Bloom's level , C: Course outcomes.***

| | | Module – 1 | M | L | C |
|---|---|---|---|---|---|
| Q.1 | a. | Define Non-traditional machining process. Write the classification of NTM. | 8 | L1 | CO1 |
| | b. | Justify the need of non-traditional machining process. | 6 | L2 | CO1 |
| | c. | List the applications of NTM. | 6 | L1 | CO1 |
| | | OR | | | |
| Q.2 | a. | Differentiate between Traditional and Non-traditional machining processes. | 10 | L2 | CO1 |
| | b. | Explain the physical parameters and process capability of the Non-traditional machining processes. | 10 | L2 | CO1 |
| | | Module – 2 | | | |
| Q.3 | a. | With a neat sketch, explain the working principle of ultrasonic machining. | 10 | L2 | CO2 |
| | b. | Explain the effector process parameters of Ultrasonic machining. | 10 | L2 | CO2 |
| | | OR | | | |
| Q.4 | a. | With a neat sketch, explain the working principle of Abrasive Jet Machining (AJM). | 10 | L2 | CO2 |
| | b. | Explain process parameters on Abrasive Jet Machining. | 10 | L2 | CO2 |
| | | Module – 3 | | | |
| Q.5 | a. | With a neat sketch, explain the working principle of Electro Chemical Grinding (ECG). | 10 | L2 | CO3 |
| | b. | Explain the following in chemical machining process: (i) Maskants (ii) Etchants | 10 | L2 | CO3 |
| | | OR | | | |
| Q.6 | a. | Explain with flow chart the chemical blanking process. Mention its applications. | 10 | L2 | CO3 |
| | b. | Describe the various process parameters affecting ECM. | 6 | L2 | CO3 |
| | c. | List the advantages and disadvantages of ECM. | 4 | L2 | CO3 |
| | | Module – 4 | | | |
| Q.7 | a. | Explain with a neat sketch, the non-thermal generation of plasma and mechanism of metal removal in PAM. | 10 | L2 | CO4 |
| | b. | With a schematic representation, explain the travelling wire EDM processes. | 10 | L2 | CO4 |

| | | | | | |
|---|---|---|---|---|---|
| | | **OR** | | | |
| **Q.8** | **a.** | Differentiate between transferred and non transferred arc plasma torch mode of operation. | **8** | **L2** | **CO4** |
| | **b.** | Explain with a neat sketch, the plasma arc machining. | **8** | **L2** | **CO4** |
| | **c.** | What are the advantages and disadvantages of EDM? | **4** | **L1** | **CO4** |
| | | **Module – 5** | | | |
| **Q.9** | **a.** | With a neat sketch, explain Laser Beam Machining (LBM). | **10** | **L2** | **CO5** |
| | **b.** | Explain the process parameters of Electron Beam Machining. | **10** | **L2** | **CO5** |
| | | **OR** | | | |
| **Q.10** | **a.** | With a neat sketch, explain Electron Beam Machining. | **10** | **L2** | **CO5** |
| | **b.** | Explain with a neat sketch, the ND-YAG laser used in the laser beam machining. | **10** | **L2** | **CO5** |

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# KLS VDIT, HALIYAL

## DEPARTMENT OF MECHANICAL ENGINEERING

## SOLUTIONS TO VTU QUESTION PAPER
[NON-TRADITIONAL MACHINING BME405A]

Fourth Semester B.E. Degree Examinations, JUNE/JULY 2024

## MODULE 1

Q. 1. a) Definition of Non-traditional Machining: It is the material removal process by using various techniques involving:

- Mechanical Energy like ultrasonic or waterjet
- Thermal energy like laser beams and plasma arc
- Electrical energy like Electric Discharge M/c.

Unlike in traditional machining these techniques can machine hard, brittle materials with complex shapes. These are applicable for delicate and small parts. The precision and surface finish is very superior.

1 b. JUSTIFICATION OF THE NEED OF NON-TRADITIONAL MACHINING: In the following cases Nontraditional machining is the only option:

(i) the material is challanging:
- Hard and brittle materials like ceramics.
- Difficult to machine parts like titanium

(ii) The shape is complex:
- Intricate shapes & features like deep cavities
- Micromachining for tiny components.

(iii) The requirements or demands:
- High precision and accuracy like aerospace and medical devices
- Superior surfacefinish in high end components.

(iv) where traditional machining is not feasible:
- No tool contact like waterjet machining
- Limited access where the area to be machined is difficult to reach for tools.

NTM is justified where traditional machining fails.

1 c. **APPLICATIONS OF NTM:**

(i) Aerospace Industry:

- High strength Temperature Resistant [HSTR] materials can only be machined by NTM. Even titanium alloys used in aerospace can be machined by NTM.
- Intricate shapes with complex geometry.

(ii) Medical Device Manufacturing:

- Biocompatible materials for surgical instruments materials like titanium, ceramics are machined using NTM.

(iii) Electronics & Semiconductor technology:

- NTM processes like LBM, EBM and chemical etching are vital for manufacturing microelectronic components.

(iv) Automotive Industry:

- NTM is employed for machining engine components

(v) Tool & Die Manufacturing:

- Carbides used in tool making can be machined by NTM.

Q 2. a) DIFFERENCES BETWEEN TRADITIONAL AND NON TRADITIONAL MACHINING:

| TRADITIONAL MACHINING | NON-TRADITIONAL MACHINING |
| --- | --- |
| (i) Cutting tool and work are always in physical contact with relative motion that results in tool wear. | (i) There is no physical contact between the tool and work piece. |
| (ii) Material Removal Rate is limited by the mechanical properties of work material. | (ii) NTM can machine difficult to cut and hard to cut materials like titanium, ceramics etc |
| (iii) Relative motion between tool & workpiece is typically rotary or reciprocating. | (iii) Many NTM processes are capable of producing complex 3-D shapes and cavities. |
| (iv) Machining of small cavities, slits, blind holes are difficult in this M/c. | (iv) Machining of small cavities, slits and production of non-circular microsized holes is possible. |
| (v) Use relatively simple and inexpensive machinery and readily available cutting tools. | (v) NTM processes require expensive tools and equipment as well as skilled labours that increases cost. |

Q 2 b) PHYSICAL PARAMETERS OF NON-TRADITIONAL MACHINING PROCESS:

(i) Energy type and level: there are different types of energy type like,

- Mechanical like abrasive flow rate, pressure
- Thermal like laser power, beam diameter
- Electrical like current, voltage etc.
- Chemical like etchant concentration.

(ii) Material properties: The workpiece material hardness, thermal conductivity, electrical conductivity and chemical reactivity play roles.

(iii) Tool Characteristics: Abrasive material hardness and size

(iv) Process Environment: Some NTM processes require certain specific environment such as vacuum required in Electron Beam machining.

## PROCESS CAPABILITY OF NON-TRADITIONAL MACHINING

(i) Material Removal Rate (MRR). This is the rate of material removed per specified time.

(ii) Accuracy and Tolerances: The precision achievable in dimensions and shape

(iii) Surface finish: The smoothness and quality of machined surface. NTM produces superior surface finishes.

(iv) Kerf width: The width of cut produced in processes like waterjet machining.

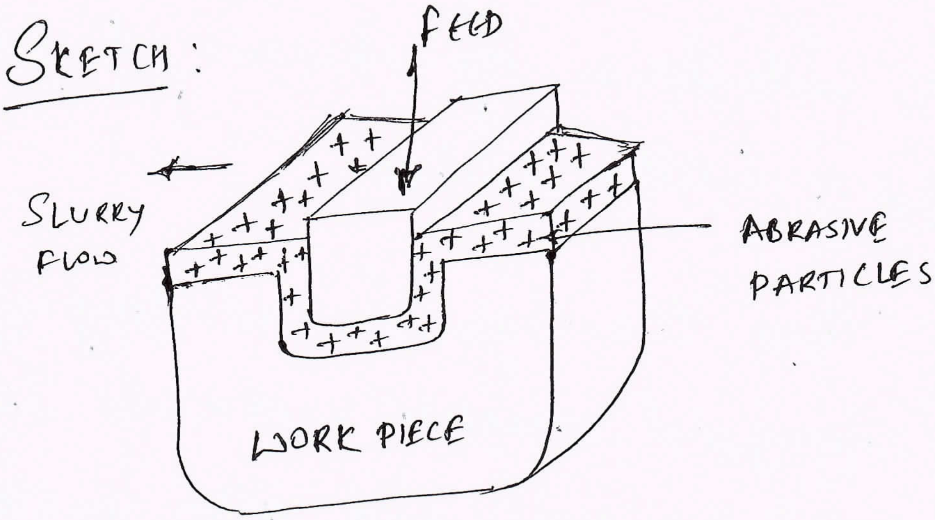
(v) Heat affected Zone (HAZ): The area of the workpiece affected by heat from the process of machining.

(vi) Material limitations: Some materials may not be machined by NTM processes.

# MODULE 2

## Q 3. a) WORKING PRINCIPLE OF ULTRASONIC MACHINING :

SKETCH :




PRINCIPLE :

- Material removal primarily occurs due to free flowing impact of abrasives on the brittle work piece.
- ~~other than~~ brittle fracture of work material, due to indentation of material removal may occur due to solid-solid impact erosion
- Tool's vibration indentation by the abrasive grits.
- During indentation, cracks would develop below the contact site, then as

indentation progresses the cracks would prop due to increase in stress and ultimately lead to brittle fracture.

— The tool material should be such that the indentation by abrasive jet grits does not lead to brittle failure.

— Thus the tools are made up of tough, strong and ductile materials like steel, stainless steel and other metallic alloys.

— The ultrasonic vibrations are produced by the transducer. The transducer is driven by suitable signal generator.

— The transducer works on the following principles — Piezoelectric effect, magnetostrictive effect and electrostrictive effect.

Q 3b).

## EFFECTIVE PROCESS PARAMETERS OF ULTRASONIC MACHINING:

(i) Abrasive Size:

→ Impact: The size of abrasive particles in slurry significantly affects the MRR or material removal rate and surface finish.

→ Coarser Grains: Generally lead to higher metal removal rate.

→ Finer Grains: Produce smoother surface finish.

(ii) Abrasive Material:

→ Hardness: Abrasive be harder than work.

→ Friability: Ability of abrasive to fracture and create new cutting edges.

→ Shape: Shape of abrasive particle can influence the cutting action & surface finish.

(iii) Slurry Concentration:

→ Denser slurry affects the impact on work surface.

(iv) Amplitude of Vibration:

→ Impact force: Higher amplitude of the tool's vibration increases the impact force of abrasive particles, leading to higher MRR.

(v) Frequency of Vibration:

→ Impact rate: Higher frequency means more impacts per unit time.

(vi) Tool force:

→ Pressure: The force applied to the tool influences the pressure exerted on the abrasive particles.

(vii) Tool material:

→ Wear resistance: The tool material should be wear resistant.

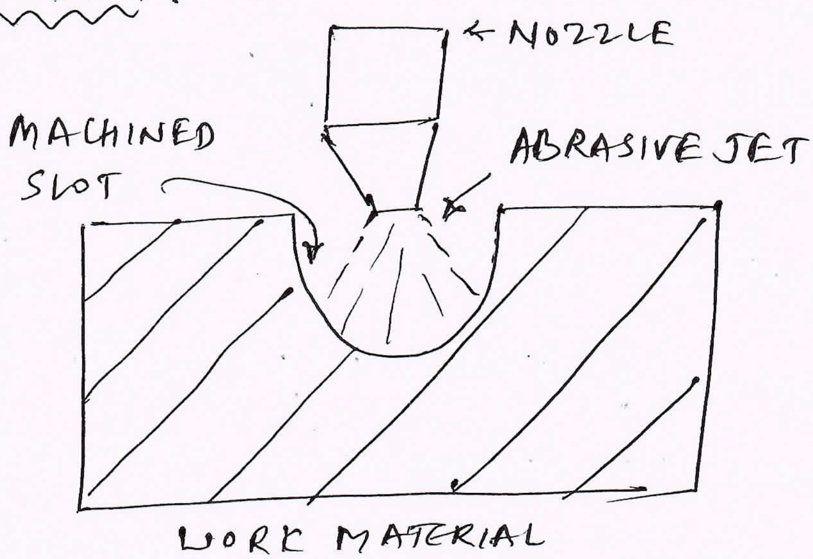
(viii) Work Material:

→ Properties: The hardness, brittleness and other properties of work material influences the USM process.

Q 4 a)

## WORKING PRINCIPLE OF ABRASIVE JET MACHINING: (AJM)

SKETCH:




PRINCIPLE: Abrasive jet machining is the NTM process that uses a high speed jet of abrasive particles carried by a gas. to erode material from the workpiece. The process contains:

(i) Pressurized gas: It is used as carrier medium.

(ii) Abrasive Particles: Fine abrasive particles such as of aluminium oxide, silicon carbide or glass beads.

(iii) Nozzle: ~~A~~ A mixture of gas and abrasive particles is forced through a focusing nozzle made of a wear-resistant material like tungsten carbide or sapphire. The nozzle directs the abrasive jet onto the workpiece.

(iv) Material removal: When a high speed jet of abrasive particles impacts the workpiece surface, it causes tiny micro-fractures and erosion, gradually removing the material.

(v) Debris Removal: The gas stream carries away the removed material particles and abrasive debris.

Q. 4. b) PROCESS PARAMETERS OF ABRASIVE JET MACHINING:

(i) Abrasive Particles:

→ Type : The abrasive material must be harder than the workpiece. Common abrasives include aluminium oxide ($Al_2O_3$) silicon carbide (SiC) etc.

→ Size : Affects material removal rate and surface finish. Coarser grains make higher MRR and rougher finish whereas finer grains make smoother finish and lower MRR.

→ Shape : Irregular shapes with sharp edges tend to cut more aggressively than the spherical particles.

→ Flow rate : The amount of abrasive particles delivered to the cutting zone per unit time.

(ii) Carrier Gas:

→ Type: Usually compressed air. The gas must be clean and dry to prevent clogging and ensure consistant performance

→ Pressure: Higher pressure increases the velocity of abrasive particles, leading to higher MRR.

→ Flow rate: Volume of gas flowing through the nozzle per unit time. It affects the velocity and concentration of abrasive particles in the jet.

(iii) Nozzle:

→ Material: Must be wear resistant.

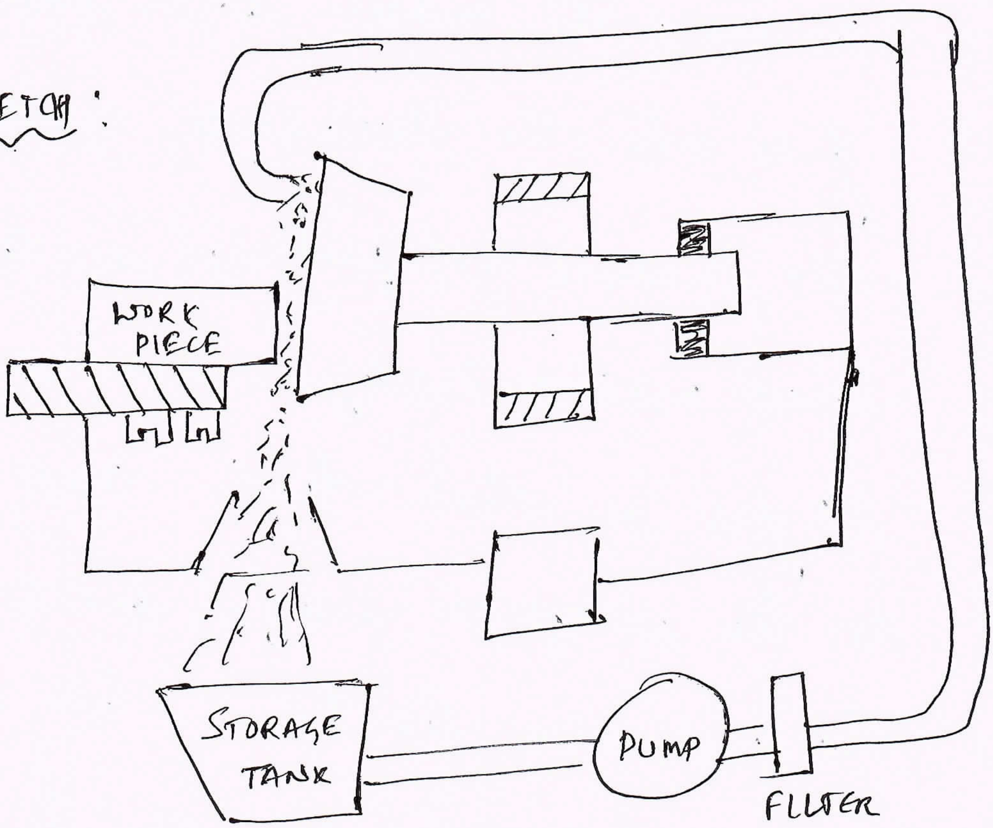
→ Size & Shape: Affect the size and shape of the abrasive jet that influences the kerf width.

→ Stand off distance (SOD) is the gap between work & tool tip.

# MODULE 3

Q 5. a) WORKING PRINCIPLE OF ELECTROCHEMICAL GRINDING (ECG):

SKETCH:




PRINCIPLE: The setup contains following

Components:
- Grinding wheel
- Workpiece
- Electrolyte

The process consists of electrochemical action. That is when DC voltage is applied between the grinding wheel and the workpiece, the electrochemical reaction occurs. The workpiece material is dissolved anodically, meaning its broken down into ions and goes into the electrolyte solution. Simultaneous the abrasive jel particles on the grinding wheel mechanically remove any oxide layers or other debris that might form on the workpiece surface due to the electrochemical reaction. This keeps the surface clean and promotes further electrochemical material removal.

5. b)

i) MASKANTS: Maskants are materials applied to specific areas of a workpiece to protect them from the action of chemicals. These act as barriers ensuring the material removal only at desired locations. Maskants make it possible to remove selected material only. They allow the creation of intricate patterns, complex shapes and fine details. Maskants safeguard delicate or other critical areas of workpiece from harsh chemicals or processing conditions that could damage them. There are different types of maskants like;

- Coatings
- Paints
- Plastics
- Elastomers.

ii) ETCHANTS:

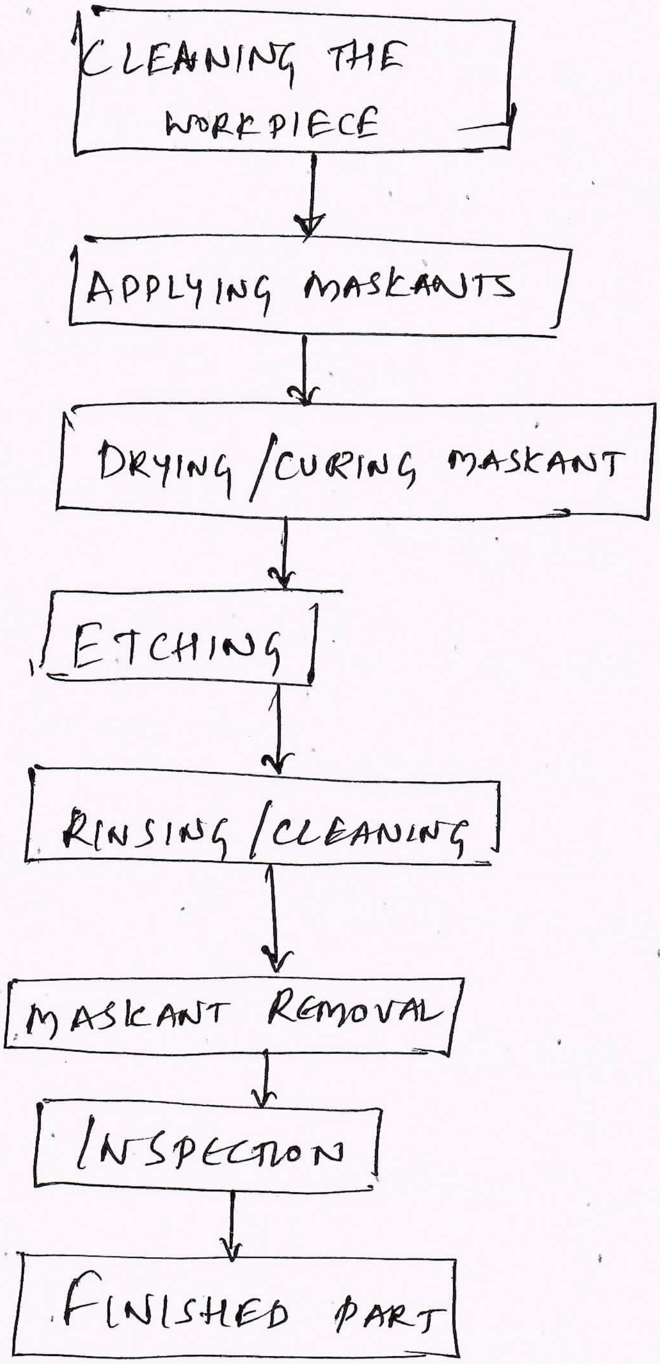
Etchants are specifically formulated chemical solutions designed to react with certain materials, causing them to dissolve or corrode in a controlled manner. This selective removal of material allows for the creation of patterns, shapes and features on the workpiece. There are different types of etchants namely;

- Wet Etchants [Acids like, $HCl$, $H_2SO_4$, $HNO_3$
- Dry Etchants

Wet etchants are liquid solutions, usually acids or bases, they are used to immerse or spray the workpiece. Dry etchants are gaseous or plasma based etchants those are used in the process like semiconductor manufacturing & microfabrication.

Q. 6 a)

## Chemical Blanking Process:




The process starts with the cleaning of the workpiece so that, no foreign material on the surface to be machined. A maskant is applied to the areas of the metal surface that are not to be etched. This can by done by spraying, dipping or painting. The maskant needs to be dried before going for actual chemical machining.

The workpiece is immersed in etchant bath

The etchant chemically removes the metal from the areas not covered by the maskant.

After completion of metal removal, the workpiece is ~~thoughroughly~~ rinsed to remove any residual etchant. Then the maskant is removed so that, ~~final~~ final part is obtained

<u>Applications</u>: i) Printed circuit boards (PCB)

ii) Microelectronic Components

iii) Semiconductor manufacturing

Q. 6. b) **PROCESS PARAMETERS AFFECTING ECM:**

(i) Electrolyte:

→ Type: Electrolyte must be chemically compatible with workpiece material and have high electrical conductivity.

→ Concentration: Affects the current density and material removal rate

→ Flow rate: Influences the removal of dissolved metal ions and heat from the machining zone that improves MRR and surface finish.

→ Temperature: Affects the electrolytes' conductivity and rate of electrochemical reactions.

(ii) Tool

→ Material: Should be conductive material

→ Shape & size: Determines the shape of cavity.

→ Tool feed rate: The rate at which the tool advances towards the workpiece

Q. 6. c) **ADVANTAGES OF ECM:**

i) Machines Hard and difficult to cut metals
ii) Produces complex shapes and intricate details
iii) Produces excellent surface finish.
iv). There is not tool wear due to no physical contact
v) Minimal force & stress on workpiece.

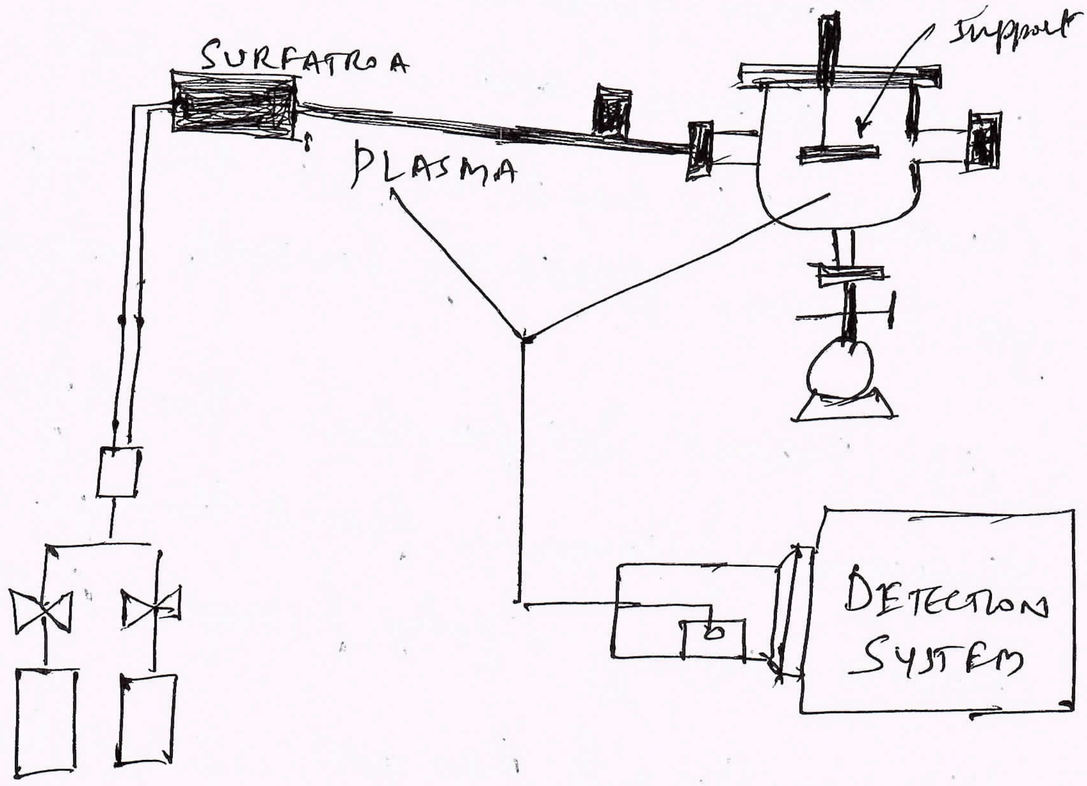
**DISADVANTAGES OF ECM:**

i) Limited to conductive materials.
ii) High initial setup costs.
iii) Specialised tooling & fixtures

# MODULE 4

Q. 7 a)

## NON-THERMAL GENERATION OF PLASMA:




The non-thermal plasma is generated by applying electric field to the gas at low pressure by following methods:

- Radio frequency discharge
- Dielectric barrier discharge
- Corona discharge
- Atmospheric pressure plasma jets

## MECHANISM OF METAL REMOVAL IN PAM:

The process of metal removal can be explained as,

i) Plasma Generation: An electric arc is created between ~~and~~ cathode and nozzle (anode) this heats the gas and superheated gas becomes partially ionized, forming plasma.

ii) Plasma Jet formation: The high temperature plasma is forced through a narrow nozzle, creating highly focussed intense jet.

iii) Melting & Removal: When the plasma jet strikes the workpiece, its extreme heat instantly melts the metal. The high velocity of gas jet then blows away the molten metal, effectively removing material.

Q. 7 b) TRAVELLING WIRE EDM PROCESS:

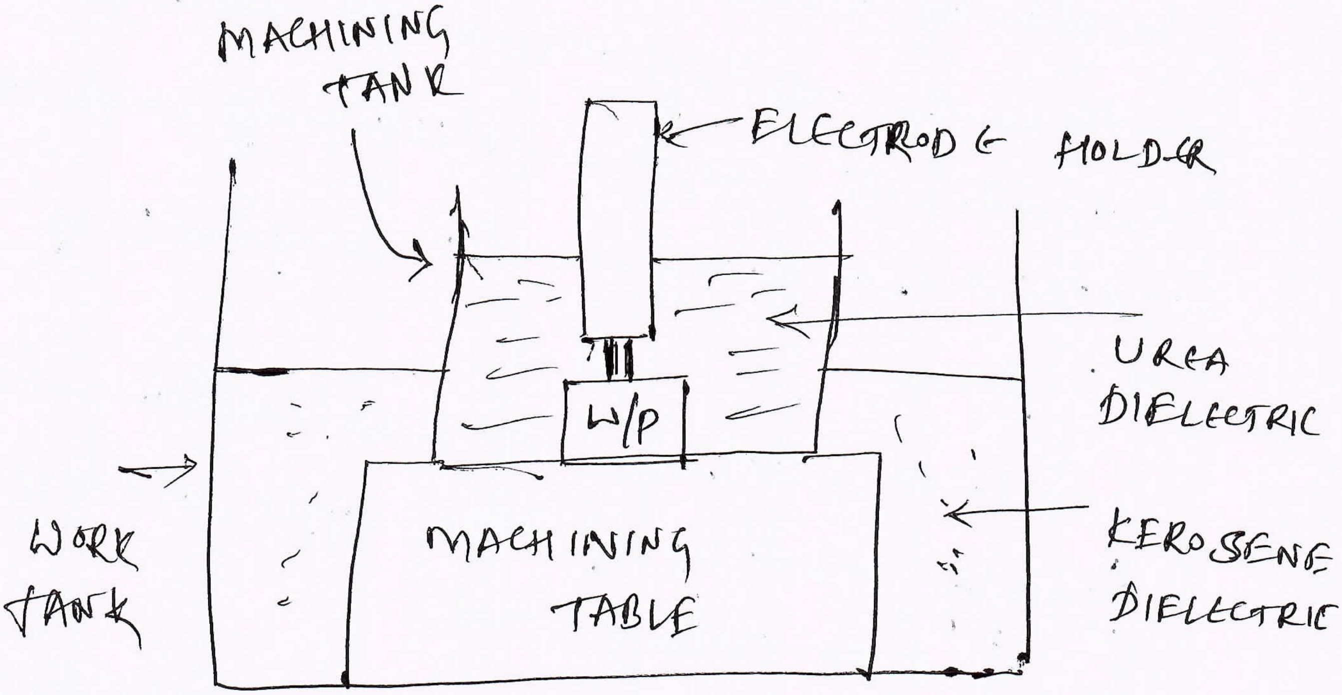
Travelling wire EDM (Electrical Discharge Machining) is a precise machining process that uses a thin, continuously moving wire as the electrode to cut intricate shapes in electrically conductive materials. Following are the components of this process:

i) Wire Electrode: ~~A~~ thin metallic wire, typically made up of brass, copper or tungsten. is used as cutting tool.

ii) Dielectric fluid: The workpiece is submerged in a dielectric fluid usually deionised water.

iii) Electrical Discharges: A high frequency pulsed DC current is applied between wire and workpiece. that creates sparks which remove the material.

(v) Material Removal: Each spark generated creates intense localized heat, melting and vaporizing a tiny amount of the workpiece material.



Q. 8. a)

**TRANSFERRED ARC PLASMA TORCH MODE OF OPERATION:**

i) In this case the electric arc is struck between the cathode inside the torch and the workpiece (anode). This means the work piece is part of circuit.

ii) The heat from the arc is directly transferred to the workpiece, making this mode very efficient for heating and melting the material.

iii) This is ideal for following processes:

- Plasma Arc Welding
- Surface hardening

**NON-TRANSFERRED ARC PLASMA TORCH MODE OPERATION**

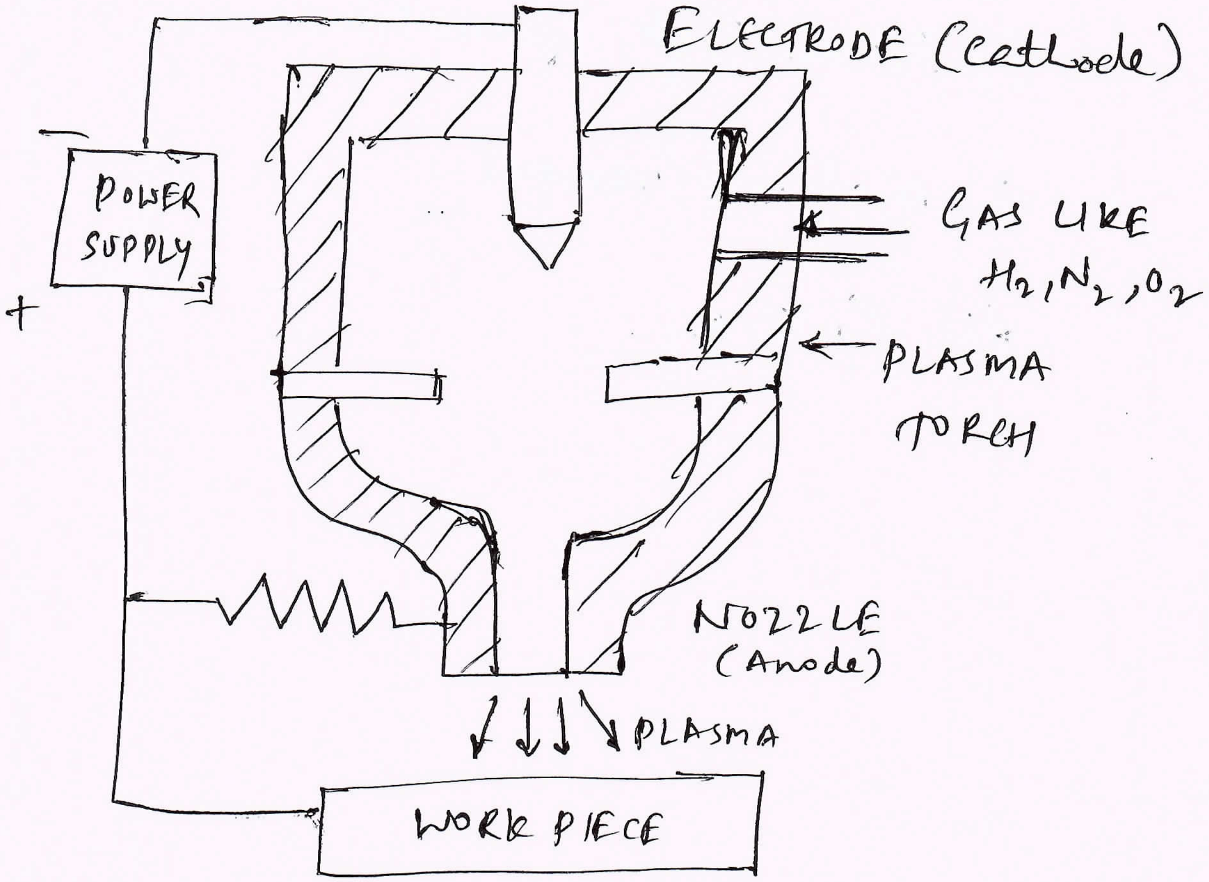
i) The electric arc is struck between cathode and nozzle (anode) within the torch itself. The arc doesn't contact workpiece.

ii) The plasma generated by the arc is expelled from the nozzle in the form of high temperature jet, which is then directed towards the workpiece.

iii) Suitable for applications where a broader area of heating is needed or when workpiece is not electrically conductive. Such as,

- Plasma Spraying
- Heating gases.
- Waste processing

Q. 8 b) PLASMA ARC MACHINING:




PAM is a thermal machining process that uses high temperature, high velocity jet of ionized gas (plasma) to remove material from a workpiece. The process is like

i) Plasma Generation

ii) Gas injection

iii) Plasma formation

iv) Nozzle constriction

v) Plasma Jet formation

vi) Materoial removal

vii) Cooling.

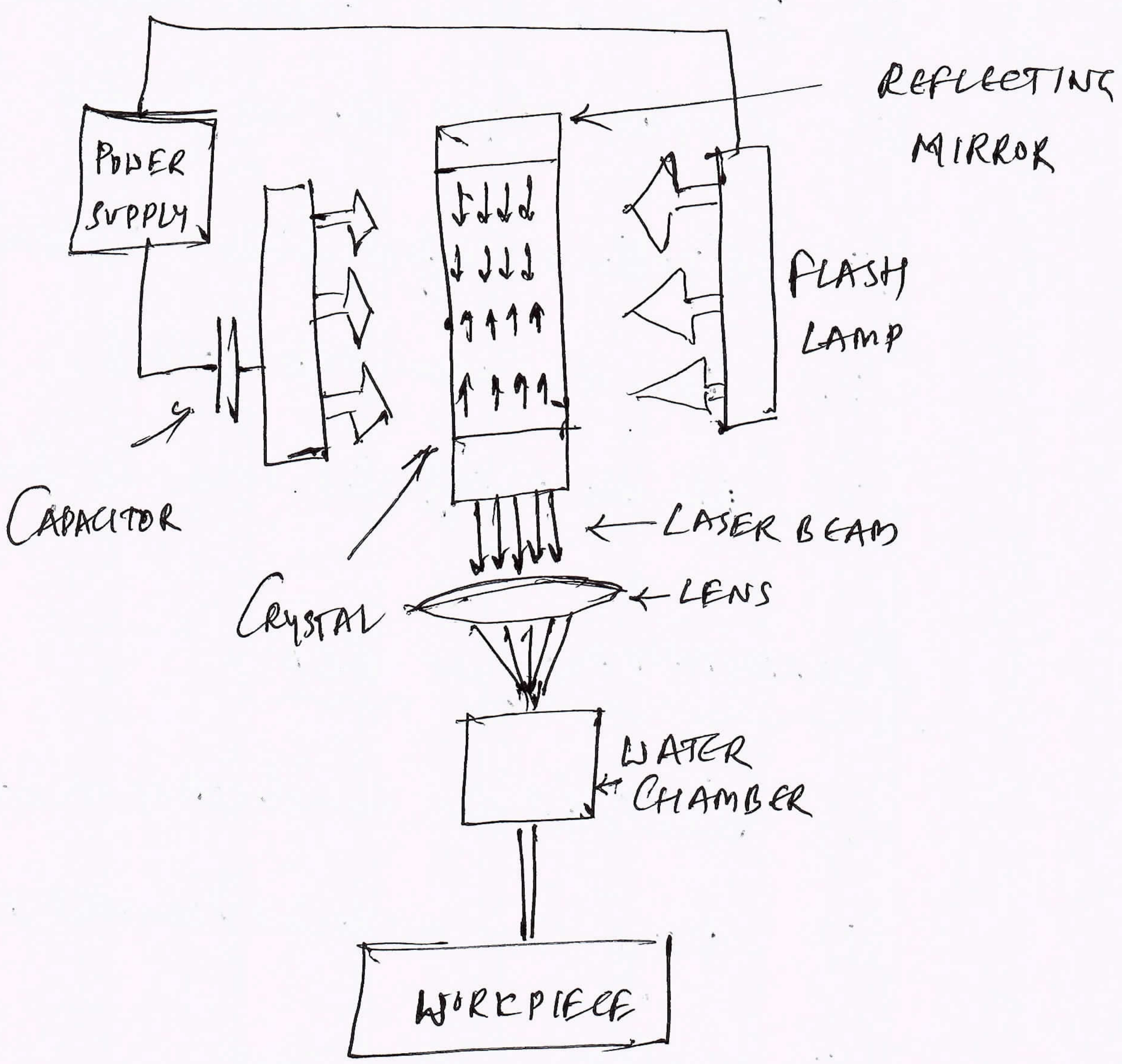
Q. 8 c) **ADVANTAGES OF EDM:**

i) It can machine harder materials.
ii) Complex shapes can be formed
iii) Excellent surface finish is obtained
iv) No tool wear takes place.
v) No-Heat Affected zone is formed.

**DISADVANTAGES OF EDM:**

i) Limited to conductive materials.
ii) Very slow material removal rate
iii) High initial cost
iv) Surface recast layer is formed.
v) High power consumption.

# Q. 9. a) LASER BEAM MACHINING (LBM)




WORKING PRINCIPLE: The process consists of.

i) Laser Generation
ii) Beam Delivery

iii) Material Removal

iv) Assist gas.

A laser source generates a high energy beam of coherent light. This light is typically monochromatic and focussed. The laser beam is directed through a series of mirrors and lenses to focus it into very small spot on the workpiece surface. When the focused light beam strikes the workpiece, its energy is absorbed by the material.

Q. 9. b) PROCESS PARAMETERS OF ELECTRON BEAM MACHINING:

i) Accelerating Voltage:

→ Impact : This determines the energy of the elections in the beams. Higher voltage means higher energy electrons.

→ Range : The range is from 50kV to 200 kV

→ Selection : Appropriate voltage depends on material being machined

ii) Beam Currents:

→ Impact : This controls the number of elections in the beam per unit time.

→ Range : Ranges from 100 to 1000 $\mu A$

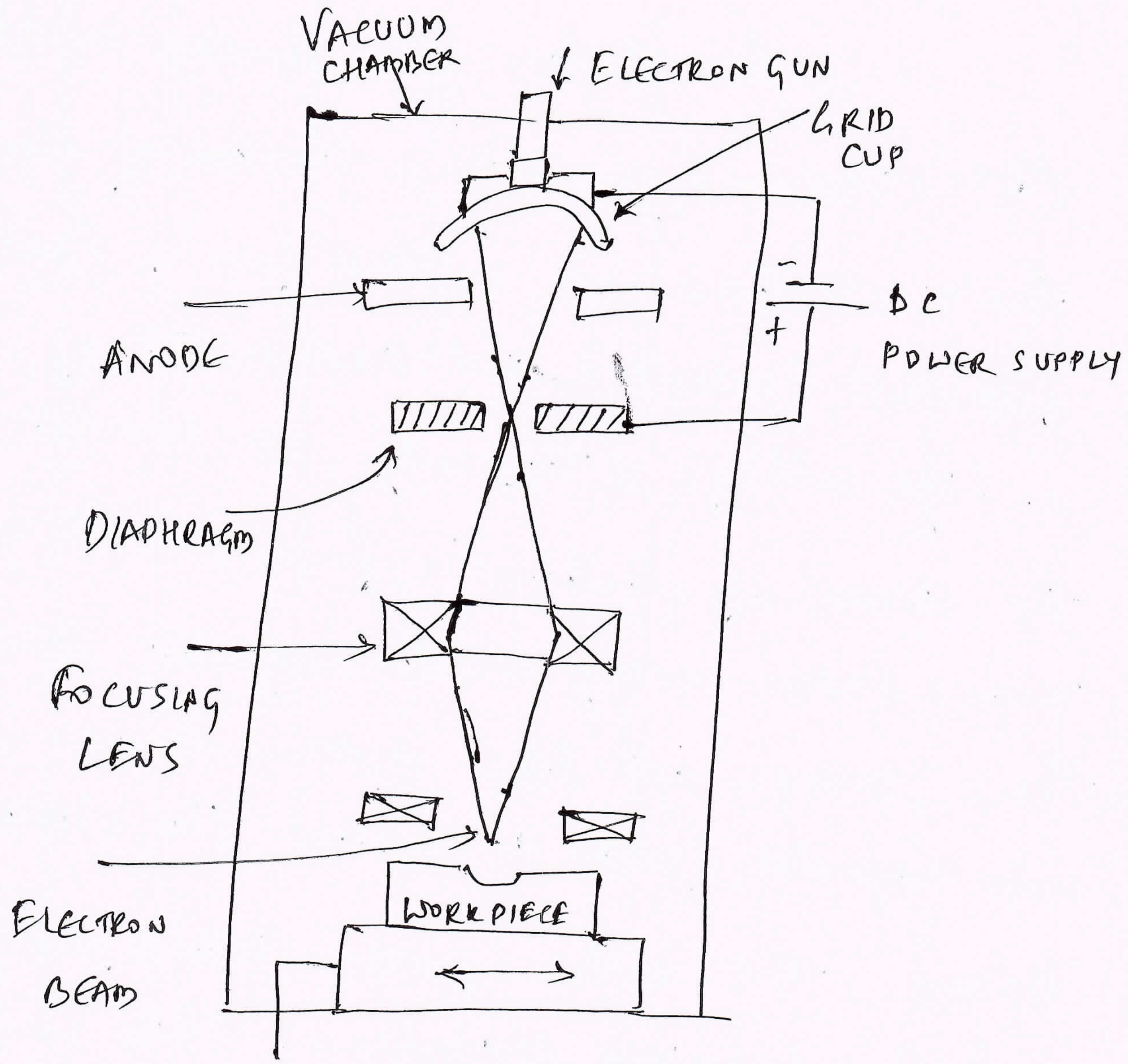
→ Adjustment : Beam is adjusted to right intensity

iii) Pulse duration:

→ Impact : The time for which pulse is on.

→ Range : It can vary from microseconds to milliseconds.

Q. 10. a) ELECTRON BEAM MACHINING:




The process of EBM works as,

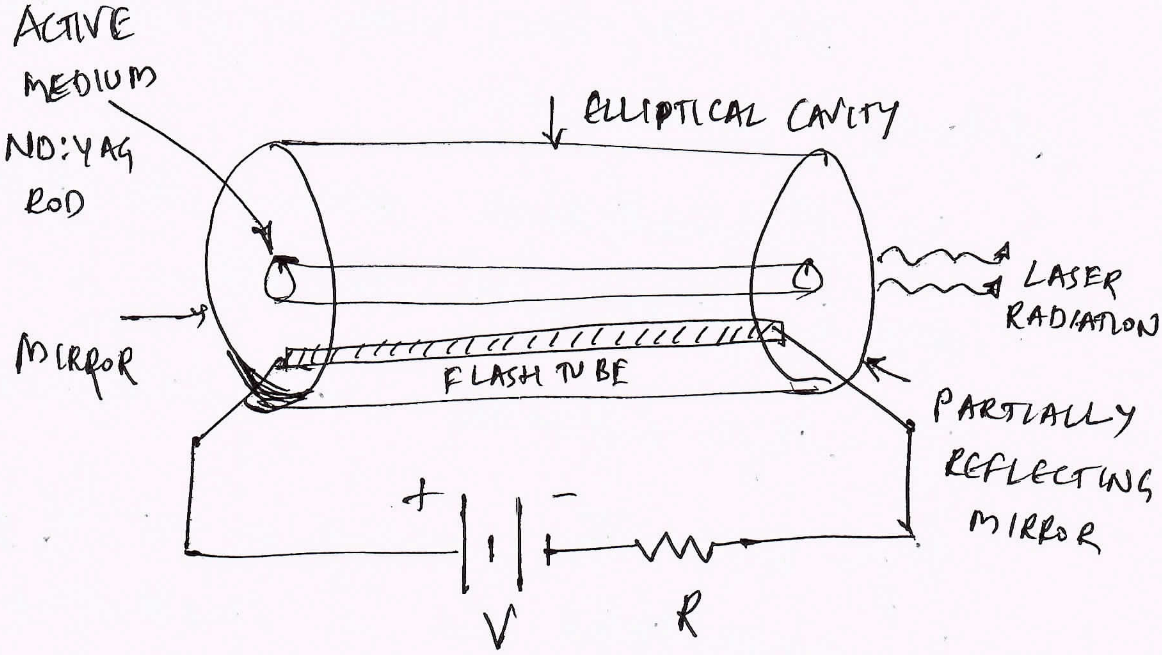
i) Electron Beam generation
ii) Beam focusing
iii) Vacuum Environment

iv) Material Removal

An electron gun similar to old CRT televisions, generates a stream of electrons. These electrons are emitted from a heated filament (cathode) and accelerated by a high voltage (typically 50-200 kV). The stream of electrons is focused into a narrow beam using electromagnetic lenses. These lenses act like optical lenses but use magnetic fields to control the electron beam. The entire process takes place in a high vacuum chamber. This is crucial because it prevents the electrons from colliding with air molecules.

Q 10. b)

## ND-YAG LASER USED IN LASERBEAM MACHINING :




### ND : YAG LASER :

ND:YAG stands for Neodymium-doped Yttrium Aluminium Garnet. This is the material used as the laser medium. It is a crystal where some of the Yttrium atoms are replaced by neodymium atoms. ND:YAG lasers are solid state lasers.

ND:YAG lasers typically emit light at a wavelength of 1064 nanometers (nm) which is in the near-infrared region of the electromagnetic spectrum.

ND:YAG laser beam is generated has following characteristics:

i) Coherent light: Means the light waves are in phase with each other.

ii) High intensity: This laser beam has high intensity, meaning a lot of power is concentrated into a small area. This allows it to be used for cutting, welding and other material processing applications.

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