



DEPARTMENT OF MECHANICAL ENGINEERING

Haldia, Purba Medinipur, West Bengal
HALDIA INSTITUTE OF TECHNOLOGY

PRACTICAL MANUAL

(Assessment Instrument and Instruction Items)

Course Name	Modern Manufacturing Process Lab
Course Code	PC-ME 692
Laboratory Name	Modern Manufacturing Lab& CAD CAM Lab
Programme	B. Tech in Mechanical Engineering
Semester / Year	VI th Semester/3 rd Year
Academic Session	2026–27

Faculty-in-Charge & Technical Staff

Faculty-in-Charge	Mr. Pritam Pain (9836584808)
Co-Faculty (if any)	Dr. Premangshu Mukhopadhyay
Technical Staffs	Mr. Debasis Maity

Vision

To impart quality, industry-oriented teaching and practical training in air-conditioning and refrigeration that integrates thermodynamic knowledge, experimental skills, modern technologies, energy efficiency, and environmental sustainability, enabling students to address real-world thermal engineering challenges.

Mission Statements

M1: To develop competent and industry-ready refrigeration and air-conditioning engineers through practical, outcome-based learning in refrigeration systems, air-conditioning systems, thermal processes, and energy-efficient technologies.

M2: To encourage experimental learning, innovation, and problem-solving skills for the analysis, design, testing, and performance evaluation of refrigeration and air-conditioning systems.

M3: To instill professional ethics, safety consciousness, environmental responsibility, and sustainable engineering practices in the selection, operation, and maintenance of modern refrigeration and air-conditioning systems.

Program Educational Objective

Graduates of B. Tech. Mechanical Engineering program, four years after graduation will

PEO1: Apply knowledge of refrigeration, air-conditioning, thermodynamics, heat transfer, and fluid mechanics to analyze, design, operate, and evaluate refrigeration and air-conditioning systems and their allied applications.

PEO2: Utilize modern engineering tools, experimental techniques, and emerging technologies to address practical problems related to energy efficiency, thermal management, refrigeration, air conditioning, and environmental sustainability.

PEO3: Demonstrate professional competence, safety awareness, ethical responsibility, effective communication, and lifelong learning while working individually or collaboratively in multidisciplinary environments related to refrigeration and air-conditioning engineering.

Program Specific Outcomes (PSOs)

PSO1: Apply knowledge of thermodynamics, heat transfer, fluid mechanics, and refrigeration principles to analyze, evaluate, and operate refrigeration and air-conditioning systems and their components.

PSO2: Utilize modern engineering tools, instruments, experimental techniques, and performance-analysis methods to design, test, troubleshoot, and optimize refrigeration and air-conditioning systems for improved energy efficiency.

PSO3: Apply professional, safety, environmental, and sustainable engineering practices in the selection, operation, maintenance, and development of refrigeration and air-conditioning systems while addressing industrial and societal requirements.

Course Details:

PC-ME 692	Category: Professional Core courses	PCIE Marks	40
Modern Manufacturing Process Lab	Semester: Sixth	PSEE Marks	60
L-T-P: 0-0-3	Credit: 1.5	Total Marks	100
Pre-Requisites: Machine Tools Lab (PC-ME 591)			
Examination (PSEE): Theory/ Drawing Assignment/ Practical/ Viva-voce/ Team work/ others			

Course Content:

Experiment and instruction items are to be framed based on these units:

Unit	Topics	Hours	CO
UNIT I	CNC Machining and Milling Part Programming: CNC system elements; axis nomenclature (X, Y, Z, A, B, C); machine and part coordinate systems; work and tool offsets; program structure; G codes (G00, G01, G02/G03, G17 to G19, G40 to G42, G90/G91); M codes (M03, M05, M06, M08, M30); contouring, pocketing and drilling cycles; simulation before execution	6	CO1
UNIT II	Robot Manipulator, Actuators and Grippers: Robot anatomy: links, joints, degrees of freedom, work envelope; configurations (Cartesian, cylindrical, spherical, articulated, SCARA); actuators (hydraulic, pneumatic, electric); drives and sensors; end-effectors and grippers (mechanical, vacuum, magnetic); basic robot programming	3	CO2
UNIT III	Electric Discharge Machining (EDM): Principle of EDM; machine elements (power supply, dielectric, servo, electrodes); parameters (pulse on/off time, peak current, voltage, gap); performance measures (MRR, tool wear rate, overcut, surface finish); effect of parameters	9	CO3
UNIT IV	Micro-EDM: Micromachining and scale effects; micro-EDM principle and applications; RC and transistor pulse generators; microcontroller-based pulse and gap control; micro-electrode fabrication; micro-hole and micro-slot machining; unstable sparking and debris	6	CO4
UNIT V	Electro-Chemical Machining (ECM): Principle (Faraday's laws, anodic dissolution, current density); machine elements; tool and fixture design; electrolytes and selection; parameters (voltage, feed rate, gap, flow, concentration); effect on MRR, accuracy and finish	9	CO5
UNIT VI	Laser Cutting: Laser fundamentals; CO ₂ laser construction and beam delivery; cutting mechanisms (melt-shear, vaporization, reactive fusion); parameters (power, speed, assist gas and pressure, focal position); kerf width, HAZ, dross, edge roughness; laser safety	9	CO6
Total		42	

Suggested Reference Books

1. Groover, M.P., Automation, Production Systems, and Computer-Integrated Manufacturing, Pearson.
2. Pandey, P.C. and Shan, H.S., Modern Machining Processes, McGraw-Hill.
3. Ghosh, A. and Mallik, A.K., Manufacturing Science, East-West Press.
4. Jain, V.K., Advanced Machining Processes, Allied Publishers.
5. Koren, Y., Computer Control of Manufacturing Systems, McGraw-Hill



Course Outcomes:

Upon successful completion of the course, students will be able to:

CO CODES	CO Statement	Knowledge Categories	Cognitive Level
PC-ME 692.1	Develop CNC milling programs using G and M codes by simulating and executing them on a CNC machine, with error-free tool paths and axis identification.	C, P	Ap
PC-ME 692.2	Explain construction, degrees of freedom, actuators and grippers of a robot manipulator by studying a laboratory robot, with correct identification of joints, drives and end-effectors.	C	U
PC-ME 692.3	Analyze EDM performance by conducting parametric experiments on an EDM machine, with accurate MRR, tool wear and overcut calculations, plotted graphs and justified parameter-wise trends.	C, P	An
PC-ME 692.4	Demonstrate the working of a microcontroller-based micro-EDM by operating the setup and machining micro-features, with correct identification of electronic circuit elements and stable spark generation.	P	Ap
PC-ME 692.5	Analyze the effect of voltage, feed rate and electrolyte on ECM performance by conducting parametric experiments on an ECM setup, with results plotted and interpreted.	C, P	An
PC-ME 692.6	Perform CO ₂ laser cutting of sheet materials by setting laser power, speed and gas pressure, with cut quality assessed through kerf width and edge finish.	P	Ap

ALIGNING OF COS IN [CL × KC] METRIC

Cognitive Levels (CL)	Knowledge Categories (KC)							
	Factual	Conceptual	Procedural	Meta-cognitive	Fundamental Design Principles	Criteria & Specifications	Practical Constraints	Design instrumentalities
Remember (R)								
Understand (U)		CO2						
Apply (Ap)		CO1	CO1, CO4, CO6					
Analyze (An)		CO3, CO5	CO3, CO5					
Evaluate (E)								
Create (C)								

Assessment Pattern and Assessment Instruments for PCIE & PSEE

Marks allotted	PCIE								PSEE (60)	
	PCAI (40)				PCAI (40)					
	10	10	10	10	10	10	10	10	40	20
CO	EX1	EX 2	EX 3	VIVA I	EX 4	EX 5	EX 6	VIVA II	GR-A	GR-B (Viva)
CO1	10			10/3					40/6	20/6
CO2		10		10/3					40/6	20/6
CO3			10	10/3					40/6	20/6
CO4					10			10/3	40/6	20/6
CO5						10		10/3	40/6	20/6
CO6							10	10/3	40/6	20/6



CO-PO & CO-PSO Articulation Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
PC-ME 692.1	2	1	2	-	3	-	-	2	1	-	2	2	3	-	2
PC-ME 692.2	2	1	1	-	2	-	-	2	1	-	2	2	1	-	2
PC-ME 692.3	3	3	1	3	2	1	1	2	2	-	1	2	2	1	3
PC-ME 692.4	2	1	2	1	3	-	-	2	1	-	3	2	3	-	2
PC-ME 692.5	3	3	1	3	2	2	1	2	2	-	1	2	2	2	3
PC-ME 692.6	2	2	1	2	2	2	1	2	1	-	2	2	2	2	2
Average	2.33	1.83	1.33	1.50	2.33	0.83	0.50	2.00	1.33	0.00	1.83	2.00	2.17	0.83	2.33

MODERN MANUFACTURING PROCESS LAB (PC-ME 692)**LIST OF ASSESSMENT ITEMS, INSTRUCTION ITEMS**

Experiment No.	Name of the experiment	Instruction Item (II)	CO Congruence
EX1 I	Study of CNC Machining System and Its Basic Elements	II1	CO1
EX1 II	Parametric study of CNC Part Programming for Milling Process		
EX2	Study of Robot Manipulator, Actuator, and Grip	II2	CO2
EX3 I	Experimental Study of EDM Process Parameters and Their Effects	II3	CO3
EX3 II	Determination of Material Removal Rate in Electrical Discharge Machining (EDM)		
EX3 III	Determination of Tool Wear Rate and Overcut in Electrical Discharge Machining (EDM)		
EX4	Study of Microcontroller-Based Micro-EDM	II4	CO4
EX5	Parametric Study of Electro-Chemical Machining (ECM) Process	II5	CO5
EX6	Study of CO ₂ Laser Cutting Process and Cutting Parameters	II6	CO6

INSTRUCTION ITEM-1(II 1)		
Experiment No.	Name of the experiment	CO Congruence
EX 1 I	Study of CNC Machining System and Its Basic Elements	[CO1]

Principle:

Axis In CNC Machine: The basis of axis identification is the 3-dimensional Cartesian coordinate system and three axis of movement are identified as x, y and z axis

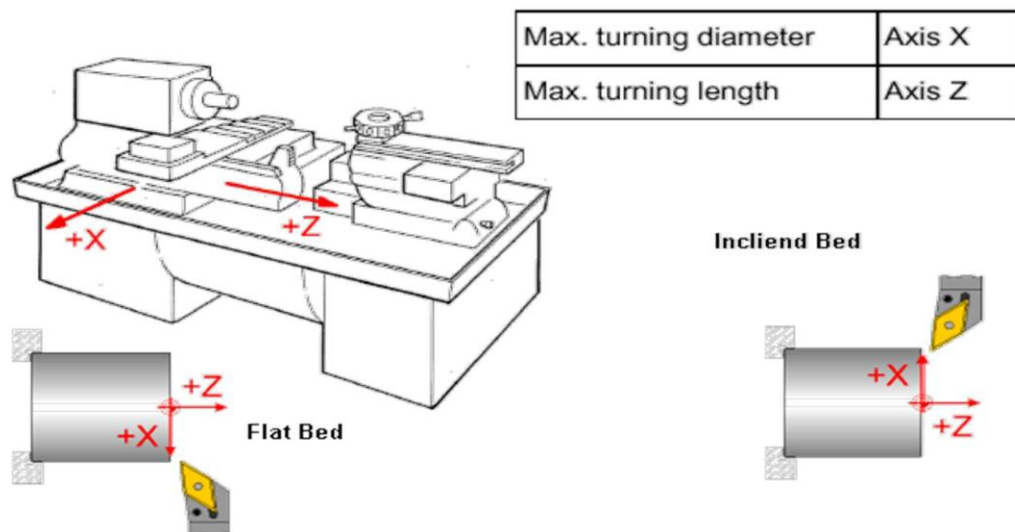
Z-axis: The Z axis of motion is always the axis of the main spindle of the machine. It does not matter whether the spindle carries the work piece or the cutting tool.

X-axis: The axis is always horizontal and is always parallel to the work holding surface. Positive X Axis movement is identified as being to the right, when looking from the spindle towards its supporting column.

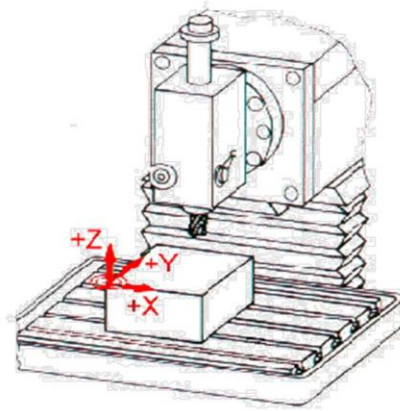
Y-axis: The axis is always at right angle to both X-Axis and Z-Axis.

Rotary axis: The rotary motion about the X, Y and Z-Axis are identified by A, B, C respectively. Clockwise is designated as +ve. Positive rotation is identified looking in x, y and z direction respectively.

AXIS IN CNC LATHE



AXIS IN CNC MILLING



Max. workpiece length	Axis X
Max. workpiece width	Axis Y
Max. workpiece height	Axis Z

The maximum workpiece dimensions correspond to the possible traversing path of the tool in the particular axis.

CNC Part Programming: The part program is a sequence of instructions, which describe the work, which has to be done on a part, in the form required by a computer under the control of a numerical control computer program. It is the task of preparing a program sheet from a drawing sheet. All data is fed into the numerical control system using a standardized format. Programming is where all the machining data are compiled and where the data are translated into a language which can be understood by the control system of the machine tool. The machining data is as follows:

- (a) Machining sequence classification of process, tool start up point, cutting depth, tool path, etc.
- (b) Cutting conditions, spindle speed, feed rate, coolant, etc.
- (c) Selection of cutting tools.

While preparing a part program, need to perform the following steps:

- (a) Determine the startup procedure, which includes the extraction of dimensional data from part drawings and data regarding surface quality requirements on the machined component.
- (b) Select the tool and determine the tool offset.
- (c) Set up the zero position for the work piece.
- (d) Select the speed and rotation of the spindle.
- (e) Set up the tool motions according to the profile required.
- (f) Return the cutting tool to the reference point after completion of work.
- (g) End the program by stopping the spindle and coolant.

Preparatory function (G-Codes).

Code	Description	Milling	Turning	Corollary info
		(M)	(T)	
G00	Rapid positioning	M	T	
G01	Linear interpolation	M	T	
G02	Circular interpolation, clockwise	M	T	
G03	Circular interpolation, counter clockwise	M	T	
G04	Dwell	M	T	Takes an address for dwell period (may be X, U, or P). The dwell period is specified in the controller's parameter, typically milliseconds.
G17	XY plane selection	M		
G18	ZX plane selection	M	T	
G19	YZ plane selection	M		
G20	Programming in inches	M	T	
G21	Programming in millimetres (mm)	M	T	
G28	Return to home position (machine zero, aka machine reference point)	M	T	Takes X Y Z addresses which define the intermediate point that the tool tip will pass through on its way home to machine zero. They are in terms of part zero (aka program zero), NOT machine zero.
G40	Tool radius compensation off	M	T	Cancels G41 or G42.
G41	Tool radius compensation left	M	T	Milling: Given right hand-helix cutter and M03 spindle direction, G41 corresponds to climb milling (down milling). Takes an address (D or H) that calls an offset register value for radius.

G42	Tool radius compensation right	M	T	Similar corollary info as for G41. Given right hand-helix cutter and M03 spindle direction, G42 corresponds to conventional milling (up milling) . See also the comments for G41.
G43	Tool height offset compensation negative	M		Takes an address, usually H, to call the tool length offset register value. The value is negative because it will be added to the gauge line position. G43 is the commonly used version (vs. G44).
G44	Tool height offset compensation positive	M		Takes an address, usually H, to call the tool length offset register value. The value is positive because it will be subtracted from the gauge line position. G44 is the seldom-used version (vs. G43).
G49	Tool length offset compensation cancel	M		Cancels G43 or G44 .
G50	Scaling function cancel	M		
G52	Local coordinate system (LCS)	M		Temporarily shifts program zero to a new location. This simplifies programming in some cases.
G53	Machine coordinate system	M	T	
G54 to G59	Work coordinate systems (WCSs)	M	T	
G54.1 P1 to P48	Extended work coordinate systems	M	T	Up to 48 more WCSs besides the 6 provided as standard by G54 to G59.

G70	Fixed cycle, multiple repetitive cycle, for finishing (including contours)		T	
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G71	Fixed cycle, multiple repetitive cycle, for roughing (Z-axis emphasis)		T	
G72	Fixed cycle, multiple repetitive cycle, for roughing (X-axis emphasis)		T	
G73	Fixed cycle, multiple repetitive cycle, for roughing, with pattern repetition		T	
G73	Peck drilling cycle for milling – high-speed (NO full retraction from pecks)	M		Retracts only as far as a clearance increment (system parameter). For when chip breaking is the main concern, but chip clogging of flutes is not.
G74	Peck drilling cycle for turning		T	
G74	Tapping cycle for milling, left-hand thread, M04 spindle direction	M		
G75	Peck grooving cycle for turning		T	
G76	Fine boring cycle for milling	M		
G76	Threading cycle for turning, multiple repetitive cycle		T	

G80	Cancel canned cycle	M	T	Milling: Cancels all cycles such as G73, G83, G81, and G86 etc. Z-axis returns either to Z-initial level or R-level, as programmed (G98 or G99, respectively).
G81	Simple drilling cycle	M		No dwell built in

G82	Drilling cycle with dwell	M		Dwells at hole bottom (Z-depth) for the number of milliseconds specified by the P address. Good for when hole bottom finish matters.
G83	Peck drilling cycle (full retraction from pecks)	M		Returns to R-level after each peck. Good for clearing flutes of chips.
G84	Tapping cycle, right- hand thread, M03 spindle direction	M		
G85	Reaming Cycle	M		
G86	Boring Cycle	M		
G90	Absolute programming	M	T	Positioning defined with reference to part zero...
G91	Incremental programming	M	T	Positioning defined with reference to previous position.
G92	Threading cycle, simple cycle		T	
G94	Feedrate per minute	M	T	
G95	Feedrate per revolution	M	T	
G96	Constant surface speed (CSS)		T	Varies spindle speed automatically to achieve a constant surface speed. See speeds and feeds. Takes an S address integer, which is interpreted as <i>sfm</i> in G20 mode or as m/min in G21 mode.

G97	Constant spindle speed	M	T	Takes an S address integer, which is interpreted as rev/min (rpm). The default speed mode per system parameter if no mode is programmed.
G98	Return to initial Z level in canned cycle	M		
G98	Feedrate per minute (group type A)		T	Feedrate per minute is G94 on group type B.
G99	Return to R level in canned cycle	M		
G99	Feedrate per revolution (group type A)		T	Feedrate per revolution is G95 on group type

Miscellaneous functions (M-Codes)

M Codes are instructions describing machine functions such as calling the tool, spindle Rotation, coolant on, door close/open etc.

Code	Description	Milling (M)	Turning (T)	Corollary info
M00	Compulsory stop	M	T	Non-optional—machine will always stop upon reaching M00 in the program execution.
M01	Optional stop	M	T	Machine will only stop at M01 if operator has pushed the optional stop button.
M02	End of program	M	T	No return to program top; may or may not reset register values.
M03	Spindle on (clockwise rotation)	M	T	The speed of the spindle is determined by the address S.
M04	Spindle on (counter clockwise rotation)	M	T	See comment above at M03.
M05	Spindle stop	M	T	

M06	Automatic tool change (ATC)	M	T	
M07	Coolant on	M	T	
M08	Coolant on (flood)	M	T	
M09	Coolant off	M	T	
M19	Spindle orientation	M	T	Spindle orientation
M21	Mirror, X-axis	M		
M21	Tailstock forward		T	
M22	Mirror, Y-axis	M		
M22	Tailstock backward		T	
M23	Mirror OFF	M		
M30	End of program with return to program top and Rewind	M	T	
M98	Subprogram call	M	T	Takes an address P to specify which subprogram to call, for example, "M98 P8979" calls subprogram O8979.
M99	Subprogram end	M	T	

INSTRUCTION ITEM-1 (II 1)		
Experiment No.	Name of the experiment	CO Congruence
EX 1 II	Parametric study of CNC Part Programming for Milling Process	[CO1]

Equipment's Required: CNC milling machine, workpiece

Procedure:

PART PROGRAMMING GEOMETRY COORDINATE SYSTEM FOR A CNC MILLING

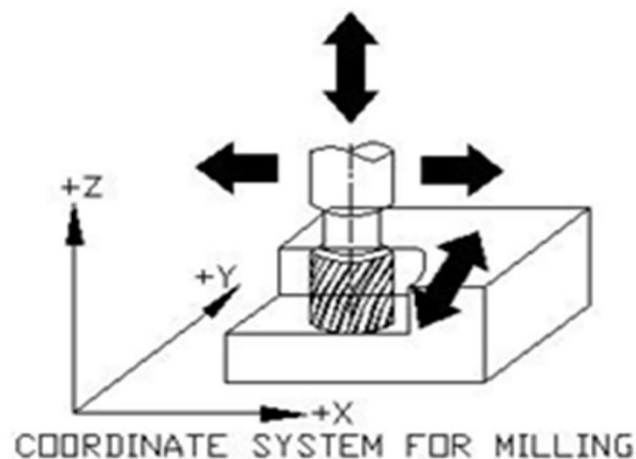
Machining of a work piece by an NC program requires a coordinate system to be applied to the machine tool. As all machine tools have more than one slide, it is important that each slide is identified individually. There are three planes in which movement can take place.

- Longitudinal
- Vertical
- Transverse

Each plane is assigned a letter and is referred to as an axis, i.e.

- Axis X
- Axis Y
- Axis Z

The three axes are identified by upper case X, Y and Z and the direction of movement along each axis is specified as either '+' or '-'. The Z axis is always parallel to the main spindle of the machine. The X axis is always parallel to the work holding surface, and always at right angles to the Z axis. The Y axis is at right angles to both Z and X axis. Figure shows the coordinate system for milling.

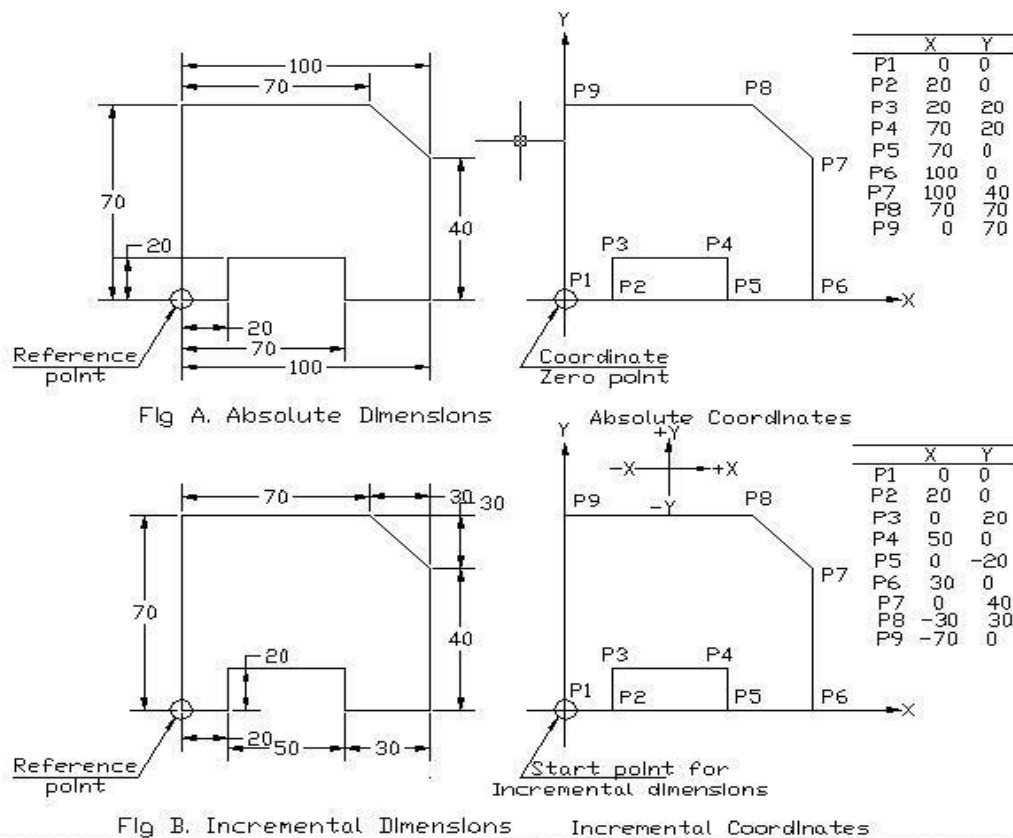


ZERO POINTS AND REFERENCE POINTS

MACHINE ZERO POINT (M): This is specified by the manufacturer of the machine. This is the x/z zero point for the coordinate systems and reference points in the machine. The machine zero point can be the center of the table or a point along the edge of the traverse range as shown in figure the position of the machine zero point generally varies from manufacture. The precise position of the machine zero point as well as the axis direction must therefore be taken from the operating instructions provided for each individual machine.

WORKPIECE ZERO POINT (W): This point determines the work piece coordinate system in relation to the machine zero point. The work piece zero point is chosen by the programmer and input into the CNC system when setting up the machine. The position of the work piece zero point can be freely chosen by the programmer within the work piece envelope of the machine. It is however, advisable to place the work piece zero point in such a manner that the dimensions in the work piece drawing can be conveniently converted into coordinate values and orientation when clamping/chucking, setting up and checking the traverse measuring system can be affected easily. For milled parts, it is generally advisable to use an extreme corner point as the "work piece zero point". Occasionally, the work piece zero point is called the "program zero point"

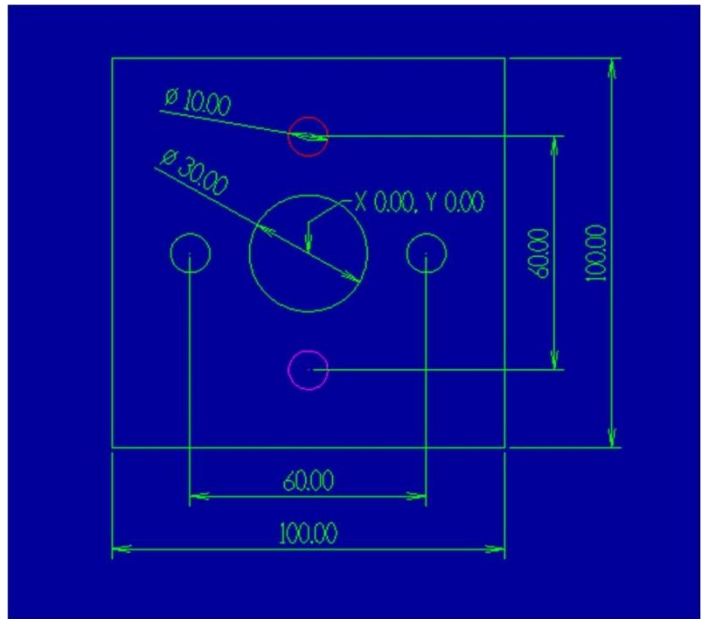
Dimensional information in a work piece drawing can be stated in two ways:



Observation: Write a CNC part program for the following milling operation.

Program for Circular Pocket

```
O0001
G28X0.0Y0.0Z0.0
M06T01
G0G54G90X0.0Y0.0
G0G43H1Z50.0
M03S1500
G01Z20.0F1500
N10
G01G90G54X0.0Y0.0F1500
G01 Z-1.0 F1000
G01 G90 G54 G42D1 X15.0 Y0.0F1500
G02X15.0Y0.0I-15.0J0.0
G01G40X0.0Y0.0
G0Z50.0
G28Z0.0
G28X0.0Y0.0
M05
M30
```



Program for Drilling

```
O0002
G28X0.0Y0.0Z0.0
M06T02
G0G54G90X30.0Y0.0
G0G43H1Z50.0
M03S1200
G01Z20.0F1500
N10
G01G90G54X30.0Y0.0F1500
G01 G83Z-10.0R1.0Q0.2F100
X0.0Y30.0
X-30.0Y0.0
X0.0Y-30.0
G0Z50.0
G28Z0.0
G28X0.0Y0.0
M05
M30
```

INSTRUCTION ITEM-2 (II 2)		
Experiment No.	Name of the experiment	CO Congruence
EX 2	Study of Robot Manipulator, Actuator, and Grip	[CO2]

Apparatus:

Sl. No.	Quantity	Nos.
1	Compressor Air Source	1
2	Industrial robot	1
3	Power supply	1
4	Gripper for holding the cylinder	1
5	Pneumatic Tubes	-



Fig: Placing the job piece



Fig: Programming in teach pendant

Procedure:

- Calibrate the robot for the given grippers.
- Feed the programming code for pick and place using Teach Pendant.
- Place the object in the desired initial position.
- Jog the robot to the desired place sequentially and save its position with desired velocity in the JOB file.
- Place the GRIPPER ON and GRIPPER OFF input at the desired position in space with the TIMER.
- After teaching, test the programming code in TEACH mode.
- Change the mode of the robot to PLAY mode for the automatic operation.

Observation:

The pick and place operation of an object through teach pendant and programming should be same.

INSTRUCTION ITEM-3 (II 3)		
Experiment No.	Name of the experiment	CO Congruence
EX 3 I	Experimental Study of EDM Process Parameters and Their Effects	[CO3]

Outline of Procedure:

Learn the name of the major parts of each machine. Understand the process of material removing in each case and identify the variables that affect the material removal rate and dimensional accuracy

Observations:

1. List the important variables (input parameters) for the processes and indicate their available range
2. Make general comments on the dimensional accuracy achievable processes from each these processes.

Theory:

Electrical discharge machining (EDM), also known as spark machining, spark eroding, die sinking, wire burning or wire erosion, is a metal fabrication process whereby a desired shape is obtained by using electrical discharges (sparks). Material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the tool or electrode, while the other is called the workpiece-electrode, or work piece. The process depends upon the tool and work piece not making physical contact. Extremely hard materials like carbides, ceramics, titanium alloys and heat-treated tool steels that are very difficult to machine using conventional machining can be precisely machined by EDM.

Summary of EDM characteristics

Mechanics of material removal	Melting and evaporation aided by cavitations
Medium	Dielectric fluid
Tool Materials	Cu, brass, Cu-alloy, graphite
Material removal rate Tool wear rate	0.1-10
Gap	10-125 J/m
Maximum material removal rate	5.103 mm ³ /min
Specific power consumption (typical)	1.8 W/mm ³ /min
Critical parameters	Voltage, capacitance, spark gap, dielectric circulation, melting temperature.
Material application	All conducting metals and alloys
Shape application	Blind complex cavities, micro holes for nozzles, through cutting of non-circular holes, narrow slots
Limitations	High specific energy consumption (about 150 times that in conventional machining), when forced circulation of dielectric is not possible, removal rate is quite low, surface tends to be rough for larger removal rates not applicable to non conducting materials.

INSTRUCTION ITEM-3 (II 3)		
Experiment No.	Name of the experiment	CO Congruence
EX 3 II	Determination of Material Removal Rate in Electrical Discharge Machining (EDM)	[CO3]

Principle:

Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut the workpiece to produce the finished part to the desired shape. The metal-removal process is performed by applying a pulse (ON/OFF) electrical charge of high-frequency current through the electrode to the workpiece. This removes the material by burning the metal layer by layer.

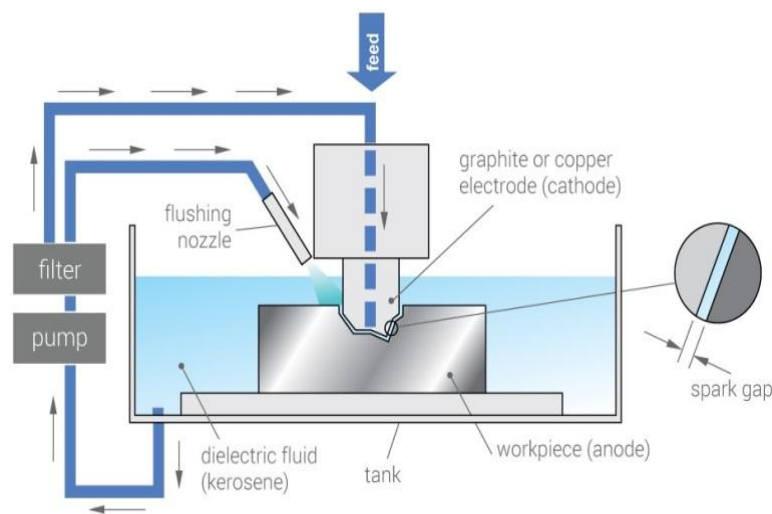


Fig: Schematic Diagram of EDM Process

Theory:

Electric-discharge machining (EDM), or spark machining, as it is also called is based on the eroding effect of an electric spark on both the electrodes used to produce it. It has been found from observation that if both electrodes are made of the same material, greater erosion occurs on the positive electrode. Hence to obtain maximum metal removal with minimum wear on the tool electrode, the work is made the positive and the tool as the negative electrode.

The tool is mounted on the chuck attached to the machine spindle whose vertical feed is controlled by the servomotor through a reduction gearbox. The workpiece is placed in a tank filled with a dielectric fluid a depth of at least 50mm over the work surface to maintain and eliminate the risk of fire. The tool and work piece are connected to a **dc** relaxation circuit. Feed either from a dc generator, or more commonly, a mercury arc or selenium-type rectifier. Dielectric fluid is circulated under pressure by a pump, usually through a hole (or holes) in the tool electrode. A spark gap of about 10-125 μm is maintained by the servomotor.

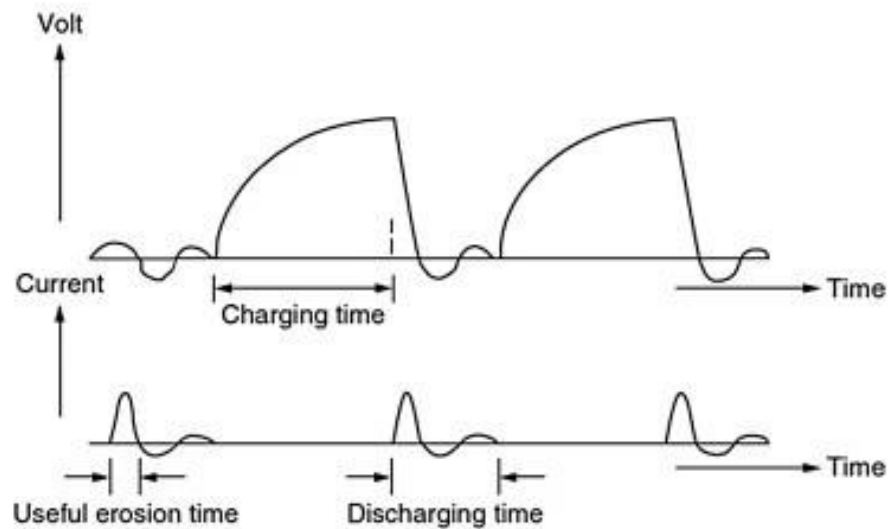
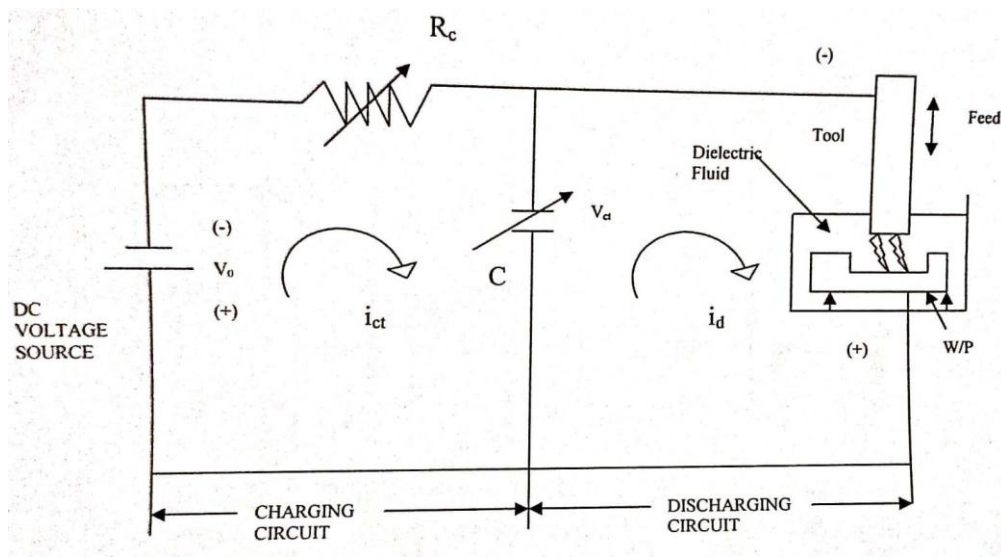


Fig: V-I Characteristic Curve

When the power supply is switched on, the condenser voltage V_c begins to increase exponentially toward the supply voltage V_s and no current flows. As the voltage V_c builds, it reaches the gap breakdown voltage V_g (determined by the gap width and the dielectric fluid); a spark is produced across the gap, the dielectric fluid ionizes and the condenser is discharged. The surrounding dielectric then deionizes so that it again becomes an effective insulator, and the cycle is repeated. In this way a rapid succession of sparks is obtained, the interval between successive sparks being of the order of $100\mu s$. Each spark generates a localized high temperature of the order of $12000^\circ C$ in its immediate vicinity. This heat causes part of the surrounding dielectric fluid to evaporate; it also melts and vaporizes the metal to form a small crater on the work surface. Since the spark always occurs between the points of the tool and work that are close together, the high spots of the work are gradually eroded, and the form of the tool is reproduced on the work. The condensed metal globules, formed during the process, are carried away by the flowing dielectric fluid. As the metal is eroded, the tool is fed in by a servo-controlled feed mechanism.

Diagram:



RLC Circuit

Determination of empirical formulae for MRR:

Sl no.	Mass of workpiece (gm)		I_p	Ton	Vg	Dia of whole	Machining Time (sec)	MRR (gm/s)
	Before	After						

Calculation of MRR:

$$\text{Material removal rate} = \frac{\text{weight before machining} - \text{weight after machining}}{\text{Machining time}}$$

INSTRUCTION ITEM-3 (II 3)		
Experiment No.	Name of the experiment	CO Congruence
EX 3 III	Determination of Tool Wear Rate and Overcut in Electrical Discharge Machining (EDM)	[C03]

Evaluation of TWR:

Tool wear rate smaller is better, 'Ip' is the most important factor then 'Vg' and last is 'Ton' .

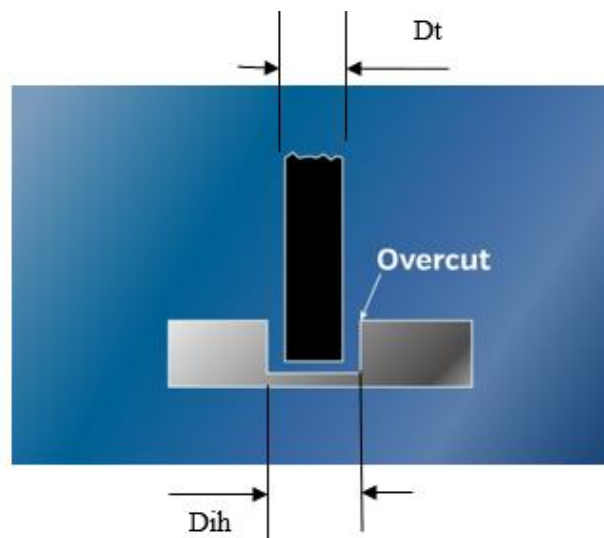


Fig: Schematic Diagram of Overcut

Evaluation of overcut:

OC is expressed as half the difference of diameter of the hole produced to the tool diameter that is shown in these equations.

$$\text{Overcut} = \frac{D_{ih} - D_t}{2}$$

Whereas D_{ih} = diameter of hole produced in the workpiece

D_t = Diameter of the tool

Observation Table:

Sl No.	Mass of the Tool (gm)		Dia of the Tool (mm)		Ip	Ton	Vg	Machining Time (Sec)	Tool Wear Rate (gm/s)
	Before	After	Before (Tdb)	After (Tda)					
1									
2									
3									

Evaluation of Tool wear rate (TWR):

$$\text{Tool wear rate} = \frac{Td_b - Td_a}{\text{Machining Time}} \text{ (gram/sec)}$$

INSTRUCTION ITEM-4 (II 4)		
Experiment No.	Name of the experiment	CO Congruence
EX 4	Study of Microcontroller-Based Micro-EDM	[CO4]

Construction of the μ -EDM Process:

Microcontroller Atmega 2560 has been used to develop the controller of this μ EDM setup. Along with that various off chip components have been used to support the microcontroller. The movement of the tool is controlled in both rotational and translational direction which is unlike in the conventional micro-EDM setup. The novelty of this set up is that there is no tool work contact. The tool feed movement as controlled by the servo mechanism, depends upon the compensation of the constant tool work gap which is almost less than one millimeter. For the translational motion each steps have been divided in four equal parts in order to attain the micro steps. Therefore, there is no vibration observed during machining unlike conventional machining processes. A program has been directly written in Arduino Integrated Development Environment (Arduino IDE). The control strategy as well as the program has been modified several time and upload to the controller time to time.

Principles of Micro EDM:

Micro EDM operates on the principle of thermal erosion caused by controlled electrical discharges between the workpiece and the electrode in a dielectric medium. The process involves the generation of high-frequency electrical sparks between the electrode and the workpiece, leading to localized melting and vaporization of material from the workpiece surface.

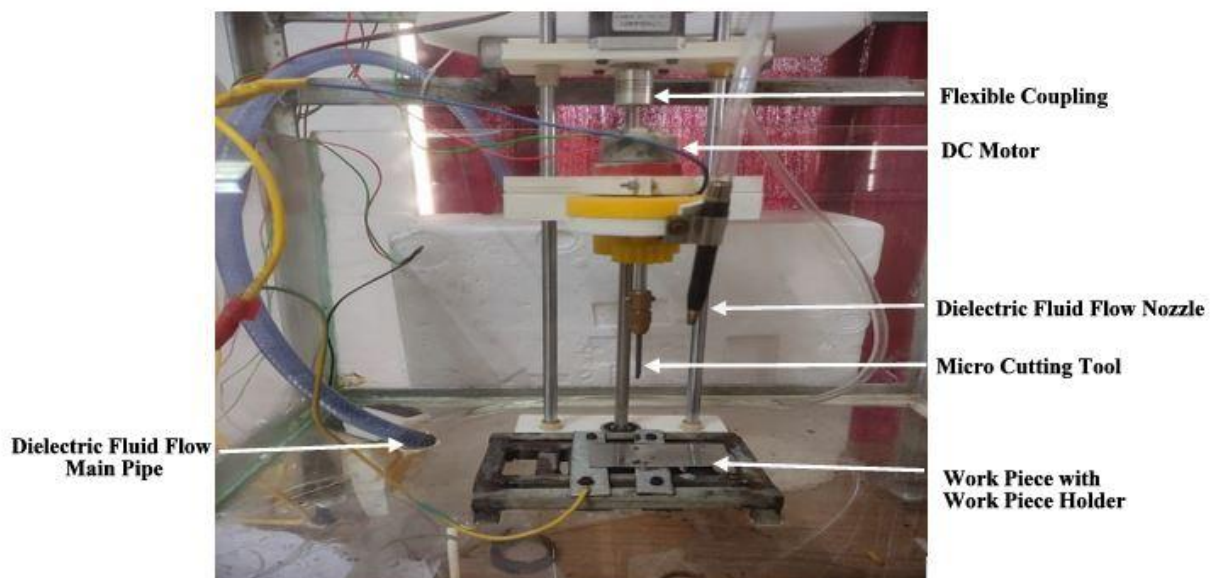


Fig: Photograph of the micro machining setup

Control variables along with their levels

Control variables	Symbol	Unit	Levels		
			1 st Level	2 nd Level	3 rd Level
Voltage	V	Volt			
Duty Factor	DF	%			
Frequency	F	Hz			
Tool Diameter	Td	mm			

Observation table:

Sl no.	Mass of workpiece (gm)		Ip	Ton	Vg	Dia of whole	Machining Time (sec)	MRR (gm/s)
	Before	After						

Calculation of MRR:

$$\text{Material removal rate} = \frac{\text{weight before machining} - \text{weight after machining}}{\text{Machining time}}$$

INSTRUCTION ITEM-5 (II 5)		
Experiment No.	Name of the experiment	CO Congruence
EX 5	Parametric Study of Electro-Chemical Machining (ECM) Process	[CO5]

Theory:

Electrochemical reactions involve the transfer of electrons between substances. In electrolysis, an external electrical energy source is used to drive a non-spontaneous chemical reaction. This process occurs in an electrolytic cell, consisting of two electrodes (anode and cathode) immersed in an electrolyte solution.

The electrolyte solution contains ions that can migrate towards the electrodes under the influence of an electric field. At the cathode, reduction reactions occur, leading to the gain of electrons. At the anode, oxidation reactions occur, resulting in the loss of electrons.

Faraday's law of electrolysis states that the amount of substance (in moles) deposited or liberated at an electrode is directly proportional to the quantity of electricity passed through the cell. Mathematically, it is expressed as:

$$\text{Amount of substance (in moles)} = \frac{Q}{nF}$$

Where:

Q = Electric charge passed through the cell (in coulombs)

n = Number of electrons involved in the reaction

F = Faraday's constant (96,485C/mol)

Experimental Setup:

1. Set up the electrolytic cell with two electrodes (cathode and anode) immersed in the electrolyte solution.
2. Connect the electrodes to a power supply.
3. Measure the initial mass of the electrodes and record.
4. Pass a known quantity of electric charge through the cell.
5. Measure the final mass of the electrodes and record.
6. Calculate the amount of substance deposited or liberated at each electrode.

Observation Table:

Sl No	Initial Mass (g)	Final Mass (g)	Change in Mass (g)	Electric Charge (C)
1				
2				
3				

Calculations:

1. Calculate the change in mass of the electrodes:
Change in Mass = *Final Mass* – *Initial Mass*
2. Calculate the electric charge passed through the cell:
Electric Charge = $I \times t$

Where:

- I = Current (in amperes)
 - t = Time (in seconds)
3. Calculate the amount of substance deposited or liberated at each electrode using Faraday's law of electrolysis.

INSTRUCTION ITEM-6 (II 6)		
Experiment No.	Name of the experiment	CO Congruence
EX 6	Study of CO ₂ Laser Cutting Process and Cutting Parameters	[CO6]

Theory:

CO₂ laser cutting is a non-contact machining process that utilizes a high-power laser beam generated from a carbon dioxide laser source to cut through various materials with precision and speed. The process involves focusing the laser beam onto the workpiece surface, which causes localized heating and vaporization of the material, ultimately resulting in a clean and accurate cut.

Key components of a CO₂ laser cutting system include:

1. **Laser Source:** Typically a CO₂ gas laser that emits a high-energy infrared beam at a wavelength of around 10.6 micrometers.
2. **Optical System:** Consisting of mirrors and lenses, the optical system directs and focuses the laser beam onto the workpiece.
3. **Workpiece Holding System:** Provides support and positioning for the workpiece during cutting.
4. **Control System:** Controls the laser parameters such as power, speed, and focal length, as well as the motion of the cutting head.

The CO₂ laser cutting process can be classified into two main modes:

1. **Vector Cutting:** In this mode, the laser follows a predefined path to cut through the material along the desired contours.
2. **Raster Engraving:** Here, the laser moves back and forth across the workpiece surface to remove material layer by layer, creating engraved patterns or textures.

Factors affecting the CO₂ laser cutting process:

1. **Laser Power:** Determines the intensity of the laser beam and thus the rate of material removal. Higher power levels allow for faster cutting speeds.
2. **Cutting Speed:** The speed at which the laser moves across the workpiece surface affects the depth and quality of the cut. Optimal cutting speed varies depending on the material and thickness.
3. **Focus Position:** Proper focusing of the laser beam is crucial for achieving clean and precise cuts. The focal point should be adjusted according to the material thickness.
4. **Gas Pressure:** In some CO₂ laser cutting systems, assist gases such as oxygen, nitrogen, or air are used to enhance cutting efficiency and remove molten debris from the kerf.

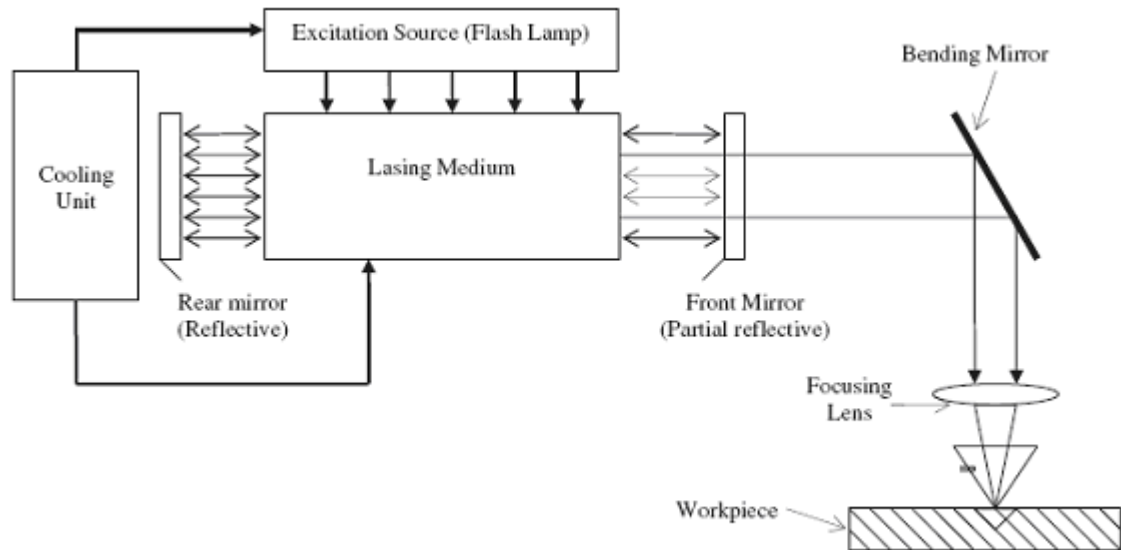


Figure: Schematic Diagram of CO₂ Laser

Observation Table:

Parameter	Setting/Value
Laser Power (W)	
Cutting Speed (mm/s)	
Focus Position (mm)	
Assist Gas Pressure	
Material Type	
Material Thickness	
Cutting Quality	
Observations	

Procedure:

1. Ensure all safety precautions are in place, including wearing appropriate personal protective equipment (PPE).
2. Power on the CO₂ laser cutting machine and initialize the control system.
3. Load the desired material onto the worktable and secure it in place.
4. Set the laser parameters including power, speed, focus position, and assist gas pressure according to the material type and thickness.
5. Execute the cutting operation and observe the process closely.

6. After cutting is complete, carefully remove the cut samples from the worktable and inspect them for quality.
7. Record observations in the observation table, noting any deviations from expected results.
8. Analyse the effects of different parameters on cutting performance and discuss findings.