

B.Tech.

Third Semester Examination, 2010-2011

Computer Aided Design (ME-203-F)

Note : Question number 1 is compulsory. Remaining out of eight solve in such a way that at least one question is attempted from each Section.

Q. 1. (i) Explain CAD/CAM/CIM.

Ans. CAD : Computer Aided Design deals with all the operations that deal with the development of product. These could include such operations as design, analysis, testing, manufacturing information generation etc.

CAM : Computer Aided Manufacturing may be defined as all the support that can be provided by the computer in the manufacturing of any given product. This role can be classified into two groups :

- (i) Computer monitoring and control of the manufacturing process.
- (ii) Manufacturing support applications which deal essentially with the preparations for actual manufacturing and post manufacturer operations.

CIM : Computer Integrated Manufacturing tries to link are the operations that are used in manufacturing such that the information is shared between all the operations. This would mean the reduction of waste leading to lean manufacturing.

Q. 1. (ii) What is homogeneous co-ordinate?

Ans. Homogeneous Co-ordinates : In homogeneous co-ordinates, an n-dimensional space is mapped into (n+1) dimensional space. Thus a 2 dimensional point $[x, y]$ is represented by 3 dimensions as $[x \ y \ 1]$. This greatly facilitates the computer graphics operations where the concatenation of multiple transformations can be easily carried out.

Q. 1. (iii) Differentiate 2-D and 3-D ICG system.

Ans. Difference between 2D and 3D ICG system :

2D	3D
(i) They include 2D geometric models such as image compositions, pixel art, digital art, photographs and text.	(i) 3-D computer graphics are graphics that use 3-D representation of geometric data. This geometric data is then manipulated by computer via 3D computer graphics software via 3D computer graphics software in order to customize their display, movements and appearance.
(ii) 2D, graphics are used everyday on traditional printing and drawing. There are 2 kinds of 3D computer graphics- Raster and Vector Graphics.	(ii) A 3D model or graphics is a mathematical representation of geometric data that is contained in a data file. 3D viewing in animations, videos, movies, training, simulation.

Q. 1. (iv) What are Analytical Curves?

Ans. Analytical Curves : This type of curve can be represented by a simple mathematical equation such as circle or an ellipse. It has a fixed form and cannot be modified to achieve a shape that violates the mathematical equations. The analytical curves are :

- | | |
|--------------|----------------|
| (i) Line | (ii) Arc |
| (iii) Circle | (iv) Ellipse |
| (v) Parabola | (vi) Hyperbola |

Q. 1. (v) Give the types of Synthetic Curves.

Ans. Synthetic Curves : An interpolated curve is drawn by interpolating the given data points and has a fixed form, dedicated by the given data points. These curves have some limited flexibility in shape creation, dedicated by the data points. The synthetic curves are :

- (i) Hermits cubic spline
- (ii) Bezier curve
- (iii) B-spline

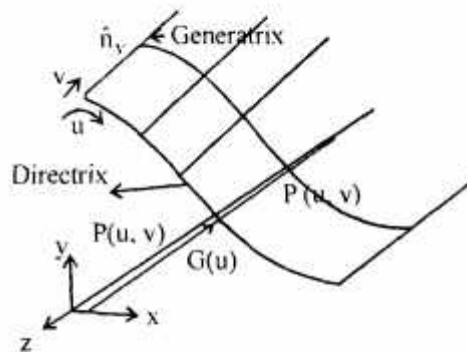
Q. 1. (vi) Why curves are represented parametrically?

Ans. As parametric equations allow great versatility in constructing space curves that are multi valued and easily manipulated.

Q. 1. (vii) Give the parametric representation of tabulated surface.

Ans. Parametric Representation of Tabulated Surface (Cylinder) : A tabulated cylinder has been defined as a surface that results from translating a space planar curve along a given direction. It can be defined as a surface that is generated by moving a straight line (called generatrix) along a given planar curve called (called directrix). This straight line always stays parallel to a fixed given vector that defines the v direction of the cylinder. The planar curve $G(u)$ can be any wire frame entities. The position vector of any point $P(u, v)$ on the surface can be written as,

$$P(u, v) = G(u) + v\hat{n}_v, \quad 0 \leq u \leq u_{\max}, \quad 0 \leq v \leq v_{\max}$$



Parametric Representation of a Tabulated Cylinder

Q. 1. (viii) Name the different level of automation.

Ans. Levels of Automation :

- Business activity
- Business information
- Organisation position
- Capability
- Location
- Basic task

Subtask activity
Automated task (and computer awareness)
Communication (and interaction timing)
Co-operation
Co-ordination.

Q. 1. (iv) Explain part families.

Ans. Part Families : A part family is a collection of parts which are similar either because of geometric shape and size or because similar processing steps are required in their manufacture. The parts within a family are different, but their similarities are close enough to merit their identifications as members of the part family.

Q. 1. (x) Discuss about CAE. (Computer Aided Engineering).

Ans. CAE (Computer Aided Engineering) : CAE involves creating computer models defined by geometrical parameters. These models typically appear on a computer monitor as a three-dimensional representation of a part or a system of parts, which can be readily altered by changing relevant parameters. CAE systems enable designers to view objects under a wide variety of representations and to test these objects by simulating real world conditions.

Section-A

Q. 2. What are important output & input devices now a days used in CAD?

Ans. Output Devices used in CAD :

(i) Graphics Displays : The graphics displays used for viewing images. It also enables the user to communicate with the displayed image by adding, deleting, blanking and moving graphics entities on the display screen. Various display technologies are now available to the user to choose from. They are all based on the concept of converting the computer's electrical signal controlled by the corresponding digital information into visible image at high speeds e.g., CRT (Cathode Ray Tube). Other technologies utilize laser, flat pannel displays or plasma panel displays. In the first a laser beam instead of an electron beam is used to trace an image in a film. In the second a liquid crystal display (LCD) and light emitting diodes are used to generate images. The pleasure display uses small neon bulbs arranged in a panel which provides a medium resolution display. Thus, for none of these display technologies has been able to displace the CRT.

The operation of CRT is based on the concept of energizing an electron beam that strikes the phosphor coating at very high speed. The energy transfer from the electron to the phosphor due to impact causes it to illuminate and glow. The electron are generated via the electron gun that contains the cathode and are focussed into a beam via the focusing unit. By controlling the beam direction and intensity in a way related to the graphics information in the computer, meaningful and desired graphics can be displayed on the screen. The graphics display can be divided into two types based on the scan technology used to control the electron beam when generating graphics on the screen. There are random and raster scan. In random scan graphics can be generated by drawing vectors or line segments on the screen in a random order which is controlled by the user input and the software.

The word random indicates that the screen is not scanned in a particular order. On the other hand in a raster scan system, the screen is scanned from left to right, top to bottom, all the time to generate graphics. This is similar to home television scan system, thus named 'digital scan.'

(ii) Hard Copy Printers and Plotters : Printers usually provide hard copy of text as well as graphics. Hardcopy devices in general employ one of two methods of plotting : vector or raster plotting.

The hard copy devices that are available include impact and non-impact devices. Impact devices include dot matrix printers and typically produce an images on paper by hammering a ribbon onto the surface of the

paper—hence the name 'impact printers'. Non-impact devices utilize other methods and include pen, pantographic, electrophotographic, electrostatic, thermal transfer and inkjet plotters and or printers.

Pen Plotters : There are two common types of conventional pen plotters. Flat bed and drum. In flat bed plotter the paper is stationary and the pen holding mechanism can move in two axes. In the drum plotter, the paper is attached to a drum that rotates back and forth, thereby providing movement in one axis.

Input Devices used in CAD :

(i) **Keyboard :** They are employed to create/edit programs or to perform word processing functions. These keyboards have been modified to perform graphics tasks by adding special function keys or attaching graphics-input devices such as mice to them.

The Programmable Function Keyboard (PFK) is another type that typically has push buttons that are programmed to eliminate extensive typing of commands or entering co-ordinate information. The push buttons are controlled by the software and may be assigned different functions at different phases of the software.

(ii) **Lightpens :** It is a pointing or picking device that enables the user to select a displayed graphics item on a screen by directly touching its surface in the vicinity of the item. The lightpen itself does not emit light but rather detects it from graphics items displayed on the screen. The user moves the pen to the vicinity of the item to be selected and then depresses the pushbutton to allow the emitted light from the item to reach the pen internal circuitry and hence to signal to the computer to select the item. The application program can then identify the segment of the data structure. Corresponding to the item detected and operated on and operate on it promptly.

(iii) **Digitizing tablets :** Digitizing tablet is a locating as well as a pointing device. It is a small, low-resolution digitizing board often used in conjunction with a graphics display. The tablet is a flat surface over which a stylus or a puck can be moved by the cursor. The close resemblance of the tablet and stylus to paper and pencil contributes to its popularity as an input device in computer graphics. The stylus is shaped like a pen and a puck is a little hand held box. The puck contains a rectifier and at least one push button. The rectifier engages cross-hairs help locate a point for digitizing. Pressing the pushbutton sends the coordinates at the cross hairs to the computer.

The tablet operation is based on sensitizing its surface area to be able to track the pointing element motion on the surface. Several sensing methods and technologies are used in tablets. The most common sensing technology is electromagnetic, where the pointing element generates an out of phase magnetic field sensed by a wire grid on the tablet surface.

(iv) **Mouse Systems :** It is a location device. There are two basic types of mice available : mechanical and optical. The mechanical mouse is a box with two metal wheels or rollers on the bottom whose axes are orthogonal in order to record the mouse motion in X and Y directions. The roll of the mouse on any flat surface causes the rotation of the wheels which is encoded into digital values via potentiometer. These values may be stored when a mouse push button is depressed. Using these values the program can determine the direction and magnitude of the mouse movement.

The optical mouse is used with a special surface (mousepad) movement over this surface are measured by a light beam modulation and optical encoding techniques. The light source is located at the bottom and the mouse must be in contact with the surface for the screen cursor to follow its movements :

(v) **Joysticks, Trackballs and Thumbwheels :** These are less popular locating devices than the tablet or the mouse. Their working operation is very similar to that of the mechanical mouse.

Q. 3. A triangle is defined as 2D ICG system by its vertices (0, 3), (0, 5) & (3, 4).

(a) Scale the original triangle by a factor of 2.5 by assuming (0, 3) as fixed point.

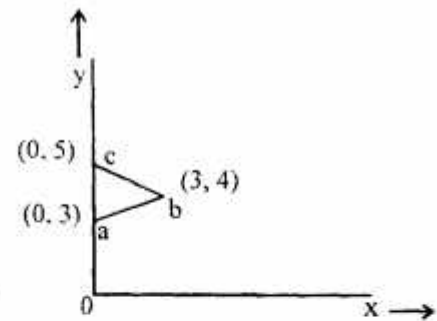
Ans. On 2-D x-y coordinates a, b and c are.

The Points :

$$a = (0, 3)$$

$$b = (3, 4)$$

$$c = (0, 5)$$



Q. 3. (b) Rotate the original triangle by 45° about the origin.

Ans.

Section-B

Q. 4. (a) Discuss the parametric representation of a circle & a hyperbola.

Ans. Parametric representation of a circle.

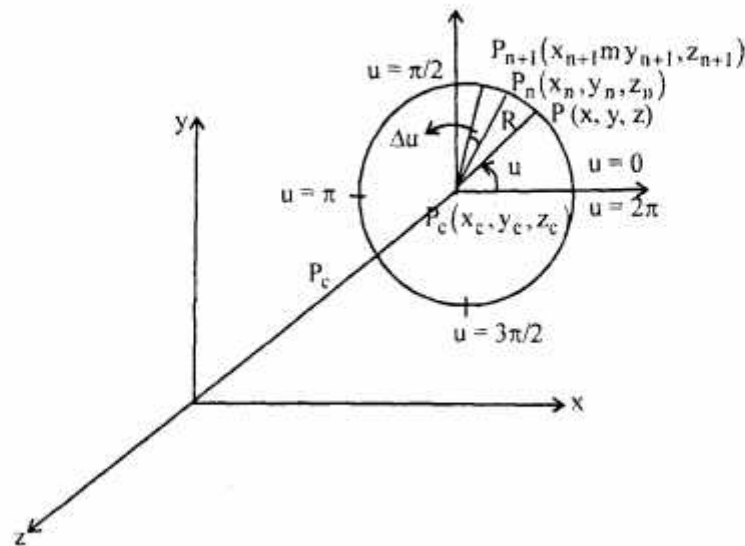
The basic parametric equation of a circle can be written as,

$$\left. \begin{aligned} x &= x_c + R \cos u \\ y &= y_c + R \sin u \\ z &= z_c \end{aligned} \right\} \quad 0 \leq u \leq 2\pi$$

Assuming there is an increment Δu between two consecutive points $P(x_n, y_n, z_n)$ and

$$P(x_{n+1}, y_{n+1}, z_{n+1})$$

On the circle circumstances,



Circle Defined by a Radius and Centre

The following recursive relationship can be written :

$$\begin{aligned}x_n &= x_c + R \cos u \\y_n &= y_c + R \sin u \\x_{n+1} &= x_c + R \cos(u + \Delta u) \\y_{n+1} &= y_c + R \sin(u + \Delta u)\end{aligned}$$

Expanding the x_{n+1} and y_{n+1} equation gives :

$$\begin{aligned}x_{n+1} &= x_c + (x_n - x_c) \cos \Delta u - (y_n - y_c) \sin \Delta u \\y_{n+1} &= y_c + (y_n - y_c) \cos \Delta u - (x_n - x_c) \sin \Delta u \\z_{n+1} &= z_n\end{aligned}$$

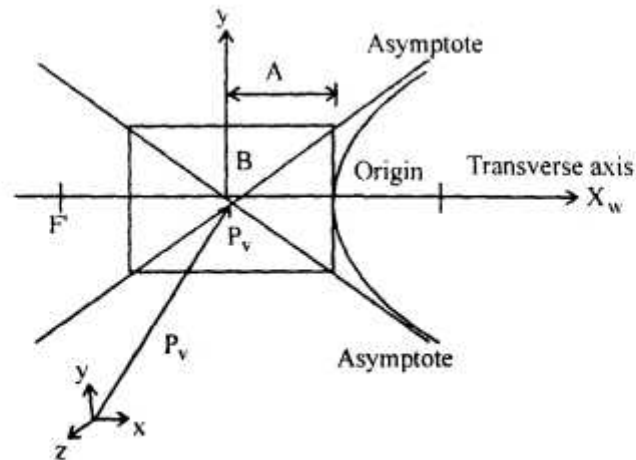
Thus, the circle can start from an arbitrary point and successive points with equal spacing. $\cos \Delta u$ and $\sin \Delta u$ have to be calculated only once, which eliminates computation of trigonometric functions for each point. This algorithm is useful for hardware implementation to speed up the circle generation and display.

Circular arcs are considered a special case of circles. A circular arc equation can be written as,

$$\left. \begin{aligned}x &= x_c + R \cos u \\y &= y_c + R \sin u \\z &= z_c\end{aligned} \right\} \quad u_s \leq u \leq u_e$$

Where, u_s and u_e are starting and ending angles of the arc respectively. An arc database includes its center and radius.

Parametric Representation of a Hyperbola : A hyperbola is described mathematically as a curve generated by a point moving such that at any position the difference of its distances from the fixed points (foci) F^+ and F^- is a constant and equal to the transverse axis of the hyperbola.



Hyperbola Geometry

The parametric equation of the hyperbola is given as,

$$x = x_v + A \cosh u$$

$$y = y_v + B \sinh u$$

$$z = z_v$$

This equation is based on the non-parametric implicit equation of the hyperbola can be written as,

$$\frac{(x - x_v)^2}{A^2} - \frac{(y - y_v)^2}{B^2} = 1$$

By using, $\cosh^2 u - \sinh^2 u = 1$.

Q. 4. (b) Explain about Hermit cubic spline & order of continuity between the joining curves.

Ans. Hermit Cubic Splines : The hermit form of a cubic spline is determine by defining positions and tangent vectors at the data points.

The parametric cubic spline curve (or cubic spline or short) connects two data (end) points and utilizes a cubic equation. Therefore, four conditions are required to determine the coefficients of the equation. When these are the positions of the two endpoints and the two tangent vectors at the points, Hermit cubic spline result. Thus the Hermit spline is considered as one form of the general parametric cubic spline. Hermitz cubic spline to a cubic spline defined by four given data points. The parametric equation of a cubic spline segment is given by

$$P(u) = \sum_{i=0}^3 c_i u^i \quad 0 \leq u \leq 1 \quad \dots(1)$$

Where, u is the parameter and c_i are the polynomial coefficients.

In scalar form this equation is written as,

$$x(u) = c_{3x} u^3 + c_{2x} u^2 + c_{1x} u + c_{0x}$$

$$y(u) = c_{3y} u^3 + c_{2y} u^2 + c_{1y} u + c_{0y}$$

$$z(u) = c_{3z} u^3 + c_{2z} u^2 + c_{1z} u + c_{0z}$$

In expanded vector form :

$$P(u) = c_3 u^3 + c_2 u^2 + c_1 u + c_0 \quad \dots(2)$$

In form of matrix, it is written as,

$$P(u) = u^T c$$

where, $U = [u^3 u^2 u^1]^T$ and $C = [c_3 c_2 c_1 c_0]^T$. C is called coefficients vector.

The tangent vector to the curve at any point is given by differentiating equation (1) w.r.t. u give

$$P'(u) = \sum_{i=0}^3 c_i i u^{i-1}, \quad 0 \leq u \leq 1 \quad \dots(3)$$

To find coefficient c_i , applying boundary conditions.

$$P_0, P'_0 \text{ at } u=0 \text{ and } P_1, P'_1 \text{ at } u=1$$

Equations (1) and (3) give

$$P_0 = C_0$$

$$P'_0 = C_1$$

$$P_1 = C_3 + C_2 + C_1 + C_0$$

$$P'_1 = 3C_3 + 2C_2 + C_1$$

Solving these four equations simultaneously for the coefficient gives :

$$C_0 = P_0$$

$$C_1 = P'_1$$

$$C_2 = 3(P_1 - P_0) - 2(P'_0 - P'_1)$$

$$C_3 = 2(P_0 - P_1) + P'_0 + P'_1$$

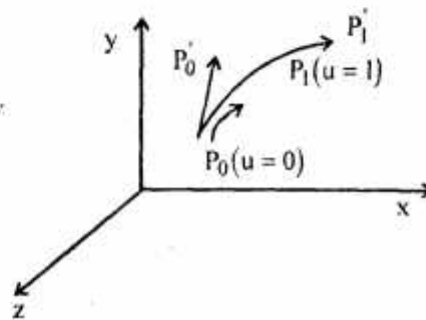
Substituting these values in equation (2), we get

$$P(u) = (2u^3 - 3u^2 + 1)P_0 + (-2u^3 + 3u^2)P_1 +$$

$$(u^3 - 2u^2 + u)P'_0 + (u^3 - u^2)P'_1 \quad \dots(4)$$

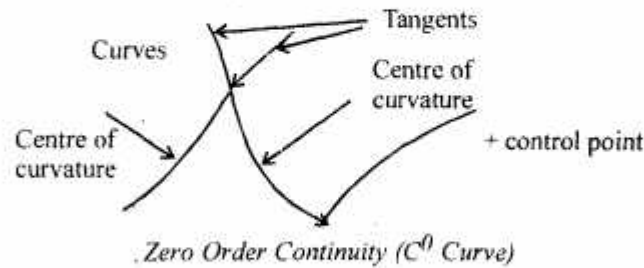
Where $0 \leq u \leq 1$

Equation (4) describes the cubic spline surface in terms of its two end points and their tangent vectors.



Hermit Cubic Spline Curve

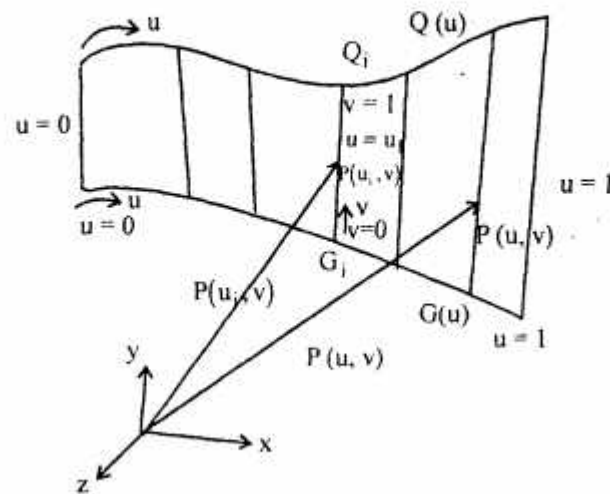
Order of Continuity Between Joining Curves : The order of continuity becomes important when a complex curve is modeled by several curve segments pieced together end to end. Zero order continuity (C^0) yields a position continuous curve. First (C^1) and second order continuity imply slope and curvature continuous curves respectively. A C^1 curve is the minimum acceptable curve for engineering design. A cubic polynomial is the minimum order polynomial that can generate of C^0 , C^1 or C^2 curves.



Q. 5. Explain the following :

- (a) **Ruled surface**
- (b) **Surface of revolution**
- (c) **Boundary representation**
- (d) **Constructive Solid Geometry.**

Ans. (a) Ruled Surface : A ruled surface is generated by joining corresponding points on two space curves $G(u)$ and $Q(u)$ by straight lines (also called rulings or generators). The main characteristics of a ruled surface is that there is at least one straight line passing through the point $P(u, v)$ and lying entirely in the surface. Every developed surface is called ruled surface. Cones and cylinders are examples of ruled surfaces and the plane surface covered.

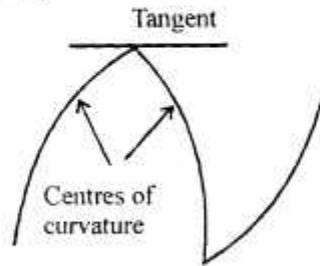


Parametric Representation of Ruled Surface

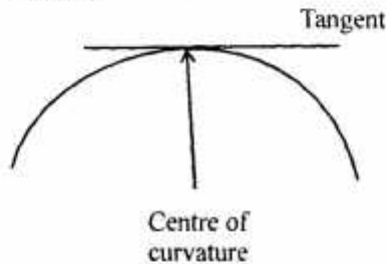
(b) Surface of Revolution : The rotation of planar curve an angle v about an axis of rotation creates a circle (if $V = 360$) for each point on the curve whose center lies on the axis of rotation and whose radius $r_2(u)$ is variable. The planar curve and the circles are called the profiles and parallels respectively while the various positions of the profile around the axis are called meridians.

The database of surface revolution must include its profile, axis of rotation and the angle of rotation as starting and ending angles.

(a) First order continuity (C^1 curves)

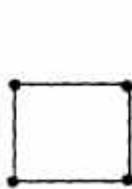


(c) Second order continuity (C^2 curve)



Higher order polynomials are not commonly used in CAD/CAM because they tend to oscillate about control points.

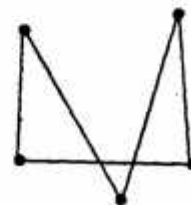
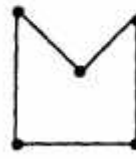
(c) Boundary Representation : Boundary representation is one of the two most popular and widely used schemes to create solid models of physical objects. A $A \rightarrow B$ -rep. model or boundary model is based on the topological notion that a physical object is bounded by a sets of faces. The faces are regions or subsets of closed and orientable surfaces. A closed surface is one that is continuous without breaks. An orientable surface is one in which it is possible to distinguish two sides by using the direction of the surface normal to point to the inside or outside of the solid model under construction. Each face is bounded by edges and each edge is bounded by vertices. Thus, topologically, a boundary model of an object is comprised of faces, edges and vertices of the object linked together in such a way as to ensure the topological consistency of the model.



(a) Original Object



(b) Modified Object



(c) Nonsense object

(d) Constructive Solid Geometry : CGS and B-rep. schedules are the most popular schemes to create solid

models of physical objects. This is apparent from the existing research and technological activities. They are the most popular because they are best understood representation thus for. CSG offers representation that are easy to create and store and easy to check for validity.

A CSG model is based on the topological notion that a physical object can be divided into a set of primitives (basic elements or shapes) that are combined in a certain order following a set of rules to form the object.

There are two main types of CSG schemes—the one is based on bounded solid primitives that is r-set. The other one is based on generally unbounded half surfaces, that is non-r sets. Bounded solid primitives are considered composite half-spaces and the boundaries of these primitives are the surfaces of the corresponding half spaces. CSG systems are based on bounded primitives (e.g., PADL-2 and GMSOLID) allow their sophisticated users to use both their bounded primitives and or half space to create new primitives, typically called metaprimitives.

Section-C

Q. 6. What is automation? Explain the types of automation with suitable examples.

Ans. Automation : Automation is defined as the technology concerned with the application of complex mechanical, electronic and computer based systems in the operation and control of production.

Automation Achievements for the Four Types of Production :

(i) **Continuous Flow Pressure :** Flow process from beginning to end sensor technology available to measure important process.

(ii) **Mass Production of Discrete Products :** Automated transfer machines dial indexing machines.

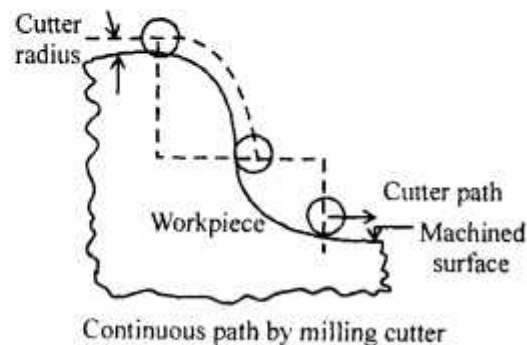
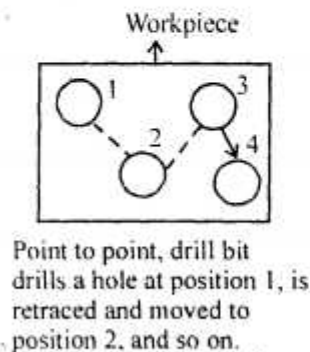
(iii) **Batch Production :** Numerical Control (NC), Direct Numerical Control (DNC), Computer Numerical Control (CNC).

(iv) **Job Shop Production :** NC and CNC.

Q. 7. (a) What are the types of NC system?

Ans. There are two basic types of control system in numerical control :

(i) **Point to Point System :** The system is also called positioning. Each axis of the m/c is driven separately by leadscrew and depending on the type of operation at different velocity. The machine moves initially at maximum velocity in order to reduce non-productive time, but decelerates as the tool approaches its numerical defined position.



Point to point system are used mainly in drilling, punching and straight milling operations.

(ii) **Contouring system (also known as Continuous Path System)** : The positioning and the operations are both performed along controlled paths at different speeds, because the tool acts as it travels along a prescribed path, accurate control and synchronization of velocities and movement are important. Continuing system is typically used on lathe, milling machines, grinders, welding machinery and machining centres.

Q. 7. (b) Explain Group Technology. What are the advantages of Group Technology?

Ans. Group technology is a manufacturing philosophy especially developed for economic production of small batches of component.

In group technology families of similar or related components with similar or related components with similar manufacturing process are identified and formed from screening diverse of unrelated parts. Thus enabling use of identical sets of machine tools and fixture are selected on the basis of size, shape and production technique. The set of machine for similar processing on families of parts are grouped into cells, each cell be capable of satisfying almost all the production requirement of the part family assigned to it. Formulation of these cell offer the potential to reduce set up cost as small batches of products belonging to the same family can be possessed together. The group technology is thus conceptually a dedicated cell of machine grouped, tooled and scheduled as unit. It does not require any computer but it can be satisfactorily implemented in worker machine environment.

Advantages of Group Technology :

- (i) It makes possible standardisation of part design and minimization of design duplication.
- (ii) Manufacturing cost can be estimated easily and the relevant statistics on materials, processes, number of parts produced and other factors can be move easily obtained.
- (iii) Process plans are standardised and scheduled more efficiently.

Section-D

Q. 8. What is Flexible Manufacturing System? Explain FMS components, their applications & benefits.

Ans. **Flexible Manufacturing System (FMS)** : Flexible Manufacturing System (FMS) has been developed to provide some of the economics of mass production to small batch manufacturing.

FMS could be considered integration of three areas :

- (i) Flexible Manufacturing Module (FMM) i.e., lathe with a robot.
- (ii) Flexible Manufacturing Cell (FMC), i.e., two or more machines tied together but robotic system to manufacturing group of designated parts or parts mix.
- (iii) FMS which is characterized by part movement from a loading station, through four, five, six or seven machines and to unloading station where a part emerges as a complete unit.

Thus, flexibility in FMS is brought about by linking together the potentially independent NC M/Cn tools, assembly m/c inspection machines (m/c), storage transportation and orientation systems for parts and toolings resulting in an overall computer control system that coordinates all the functions.

Advantages or Benefits of FMS :

- (i) Reduction cost per part.
- (ii) Reduction of throughout times and increasing flexibility towards changes of the product mix.
- (iii) Reduced inventory cost and lead times.
- (iv) Increased productivity.

Applications : To hold the parts, tools and deciding the machining parameter moving the part to m/c

properly position and set up, removing part after machining to the next station etc. FMS would automate all the above operation through direct numerical control (DNC).

Q. 9. (a) Drive the shape function for linear solution.

Ans. Let us consider a simple element, assuming linear displacement.

$$u = ax + b \quad \dots(1)$$

At node i

$$u_1 = ax_1 + b \quad \dots(2)$$

At node j

$$u_2 = ax_2 + b \quad \dots(3)$$

Subtracting equations (2) from (3), we get

$$u_2 - u_1 = ax_2 - ax_1$$

$$\frac{u_2 - u_1}{x_2 - x_1} = a \quad \dots(4)$$

Substituting equations (4) in (2), we get value of b as

$$u_1 - \left[\frac{u_2 - u_1}{x_2 - x_1} \right] \times x_1 = b \quad \dots(5)$$

Now equation (1) can be written as,

$$u = \left(\frac{u_2 - u_1}{x_2 - x_1} \right) \times x + u_1 - \left[\frac{u_2 - u_1}{x_2 - x_1} \right] \times x_1$$

After rearranging the terms, we get

$$u = \left(\frac{u_2 - u_1}{x_2 - x_1} \right) \times x + \left[\frac{u_1 x_2 - u_2 x_1}{x_2 - x_1} \right]$$

Further rearranging, we get

$$u = \left(\frac{x_2 - x}{x_2 - x_1} \right) \times u_1 + \left[\frac{x - x_1}{x_2 - x_1} \right] \times u_2$$

i.e.,

$$u = N_1 u_1 + N_2 u_2$$

Where,

$$N_1 = \left[\frac{x_2 - x}{x_2 - x_1} \right]$$

$$N_2 = \left(\frac{x - x_1}{x_2 - x_1} \right) \text{ and are called as shape functions.}$$

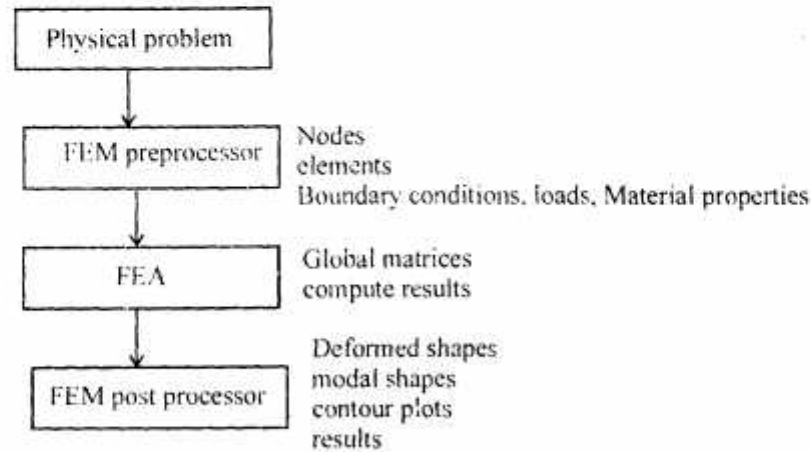
Q. 9. (b) What is FEM? Explain the different steps of finite element modeling. Also write down the elemental stiffness matrix for linear solution.

Ans. FEM : FEM or Finite Element Method is a mathematical technique used to predict the response to structures and materials to environmental factors.

Finite element method is very powerful tool for getting the numerical solution of a wide range of engineering problems. The basic concept is that a body or structure may be divided into smaller elements of finite dimensions called as "finite elements." The original body or structure is then considered as an assemblage of these elements connected at a finite number of joints called as "Nodes or Nodal points." The properties of the elements are formulated and combined to obtain the properties of the body.

Steps Involved in Finite Element Modeling are :

- (i) Converting to geometry into the discretised elements and calculating various properties for each element such as geometry, material properties, constraints and loading. This forms the input for the analysis.
- (ii) Assembling the global equations from the formulation specified in the previous stage and then solving the governing equations and obtaining the results.
- (iii) Interpreting the results in the specific form depending upon type of problem solved.



Element Stiffness matrix $[K]^e$ is given by

$$[K]^e = \int_{\Lambda^e} [B]^T [D] [B] dV$$

$$= t \int_{\Lambda^e} [B]^T [D] [B] dA$$

Ans.