Principles and Practices of CAD/CAM

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CAD/CAM systems are perhaps the most crucial advancement in the field of new technology relating to engineering, design and drawing in all technical domains. CAD/CAM stands for computer-aided design and computer-aided manufacturing. These systems are useful in all facets of contemporary design and architecture. The fundamentals of CAD/CAM systems are covered in detail throughout this book.

This book aims to introduce the fundamental aspects, complete with an adequate number of illustrations and examples, without delving too deeply into the specifics of the subject matter. This book is valuable in the classroom for both teachers and students.

Features

- Each chapter begins with the Learning Outcomes (LOs) section, which highlights the critical points of that chapter.
- All LOs, solved examples and questions are mapped to six Bloom Taxonomy levels (BT levels).
- Offers fundamental concepts of CAD/CAM without becoming too complicated.
- Solved examples are presented in each section after the theoretical discussion to clarify the concept of that section.
- Chapter-end summaries reinforce key ideas and help readers recall the concepts discussed.

Students and professionals need to have a working knowledge of CAD/CAM since it has many applications and continues to expand. Students at the undergraduate and graduate levels of engineering courses use this book as their primary textbook. It will also be helpful for managers, consultants and professionals.

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Preface

The globalisation of the economy necessitates the development of new products that have improved characteristics at prices that are competitive. Another difficulty arises from the shortening of the product's lifespan. Because of this, the time required for the product development cycle has to be significantly compressed. Engineers today use CAD/CAM systems for every activity because of the tremendous increases in processing power and the broader availability of software tools for design and manufacturing.

The idea behind this book is straightforward, yet it works quite well. In order for the reader to become successful in utilising any CAD/CAM system, they need to obtain information from a source that is both thorough and complete. This expertise covers a comprehension of the design process, the role of computers in design and production, geometric modelling, computer graphics, three-dimensional modelling, the principles of computer-aided manufacturing (CAM) and numerically controlled (NC) part programming. In addition to that, the topics covered in this book include the principles of automation, automated material handling and inspection and industrial robots. In light of these considerations, readers should find this book helpful since it offers a comprehensive solution to all of their CAD/CAM, automation and industrial robot education requirements under one roof.

MAPPING WITH BLOOM'S TAXONOMY

The main feature of this book is the mapping of chapters with the revised Bloom Taxonomy Level (BT level). Bloom's Taxonomy was created to promote a higher level of cognitive thought, such as analysis, evaluation and creation, rather than simply to remember facts. Bloom's Taxonomy has six learning stages from the lower level through to higher-level thinking.

BT level 1. Remembering: Recall information or data.
BT level 2. Understanding: Understand the meaning of written, oral and graphics.
BT level 3. Applying: Applying a concept in a new situation.
BT level 4. Analysing: Breaking down the concepts into the constituent parts and drawing inferences.
BT level 5. Evaluating: Making judgements based on standards and sets of criteria.
BT level 6. Creating: Create a new thing or model based on prior learning.

All chapter learning outcomes, solved examples, questions and practice problems are mapped to a Bloom's Taxonomy level.

PEDAGOGICAL FEATURES

This book includes a variety of valuable pedagogical features to help the readers understand and retain the content.

1. Each chapter begins with the Learning Outcomes (LOs) section, which highlights the critical points of each chapter,
2. LOs are presented in the box within the specific section of each chapter,
3. Solved examples are presented in each section after the theoretical discussion to clarify the concept of that section,
4. At the end of each chapter, a summary reinforces key ideas and helps readers recall the concepts discussed,
5. Questions are provided at the end of each chapter to test the understanding of the concept discussed in the chapter,
6. Competency checks using six levels of Bloom's Taxonomy help readers assess their understanding of the material.

Acknowledgements

We would like to thank our colleagues and our family members for their encouragement and moral support in bringing this book to fruition. We do appreciate CRC Press for their diligent effort in rendering this book elegant, in a prompt manner.

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1 Introduction to CAD

Learning Outcomes: After studying this chapter, the reader should be able

LO 1: To understand computer-aided engineering (BT level 2).
LO 2: To understand product lifecycle management (BT level 2).
LO 3: To understand the design process and application of computers in design (BT level 2).
LO 4: To understand computer fundamentals: computer input devices, output devices and CPU (BT level 2).

VIDEO 1

1.1 INTRODUCTION TO COMPUTER-AIDED ENGINEERING (CAE)

LO 1. To understand Computer-Aided Engineering (CAE)

CAE refers to any use of computers to solve engineering problems. Computer-assisted processes include computer-aided design (CAD), computer-assisted manufacturing (CAM), computer-integrated manufacturing (CIM), computer-assisted analysis (CAA), material requirements planning (MRP) and computer-assisted planning (CAP). CAE is the use of software to forecast or analyse the mechanical, thermal, magnetic or other qualities and states of a system. Software for CAE may simulate the effects of wind, temperature, weight and stress on the design or assembly of a product. Before committing to actual construction, engineers may model the effects of stress on components of an internal combustion engine, such as pistons, or on structures, such as bridges or aircraft wings, using computers.

CAE is the use of interactive computer graphics to solve engineering issues, made feasible by the rapid growth of computing technology and the improvement of graphics displays, engineering workstations and graphics standards. CAE software may run on mainframes, supercomputers, minicomputers, engineering workstations and even personal computers. The selection of a computer system is influenced by the processing capacity required by the CAE application software or the desired degree and speed of graphical interface. Increasing numbers of firms are using engineering workstations. A typical CAE software package consists of several mathematical models encoded in algorithms developed in a suitable programming language. An engineering model represents the phenomenon being studied. A geometric model may be used to describe the physical arrangement. On a display device such as a cathode ray tube (CRT), liquid crystal display (LCD), or plasma display, the user interface displays the results alongside the geometry. CAE can be coupled with optimisation systems to find iterative solutions to the engineering design problems, thus improving productivity and the quality of design.

Figure 1.1 illustrates a CAE application running on a computer used in engineering. To begin a physical analysis, mathematical equations representing the phenomenon of interest must be written. Equations like Newton's second law may be used in this engineering model to explain the behaviour

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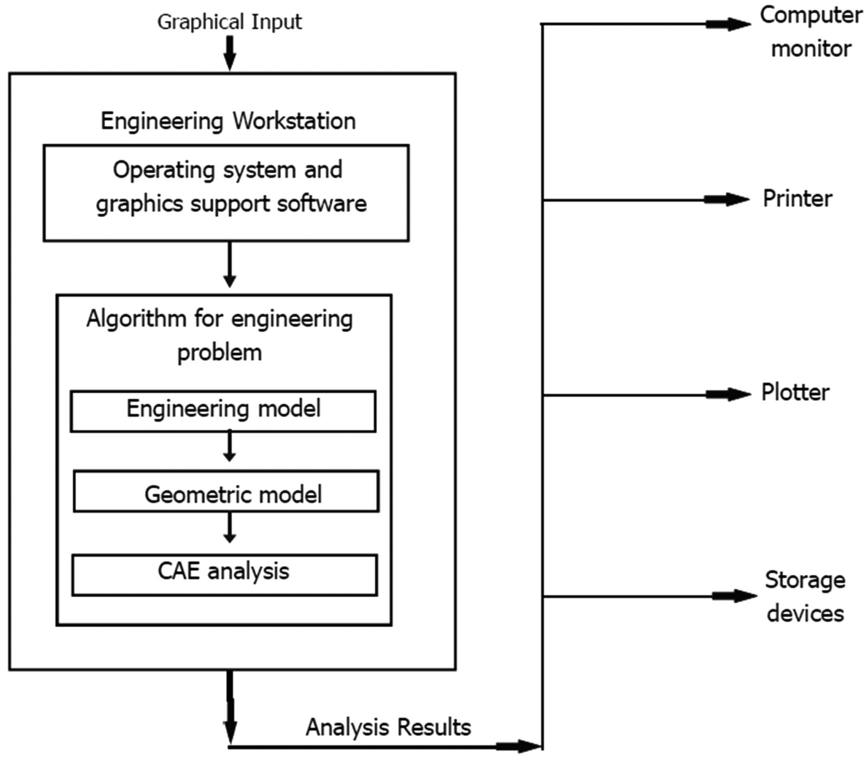

FIGURE 1.1 CAE system

of a spring-mass-damper system, for instance. The next step is to construct an analogue of the actual setup. This geometric model may include lines, surfaces and solids of any number of dimensions. Displaying the outcome of an engineering study on a geometric model by changing the colour and intensity of a scalar parameter is a common practice. The contemporary software makes use of special rendering schemes to improve the display of results.

Each product and service has a finite lifetime. Lifecycle refers to the period between a product's debut on the market and its final retirement. For any company, whether it is an automobile manufacturer or any other engineering goods manufacturer, the lifecycle of a product is something that must be understood and managed properly. So, let us try to understand it briefly.

1.2 PRODUCT LIFECYCLE MANAGEMENT (PLM)

LO 2. To understand Product life cycle management

The purpose of PLM is to manage a product from its conception to its ultimate decommissioning. The management structure of PLM is applicable to the software and service sectors in addition to the manufacturing industry. There are typically five distinct stages that make up a product's lifecycle or phases (Figure 1.2):

1. Product development,
2. Product introduction,
3. Product growth,
4. Product maturity,
5. Product decline.

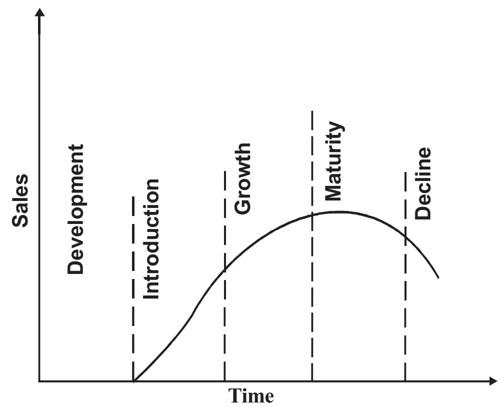

FIGURE 1.2 Product lifecycle curve

Figure 1.2 illustrates these phases. The first phase is the beginning of life, which includes new product development and design processes. When a company develops a new product idea, it enters the product development phase. We translate and integrate new information into an existing product as part of this procedure. In the beginning, while a product is still in the testing phase, there are no sales. Today is a day when money may be spent without the possibility of recovering it. When a product reaches its second phase, known as "introduction," it is made available to the general public. During this period, it is common to invest heavily in marketing and promotion, and it is often necessary to execute new service requirements fast at the price of quality. As product sales surge during the growth period, this is the opportunity to reap the rewards of the investment. Now is the time to make further efforts to increase market share. This level encompasses supply chain coordination, controlled product data and warranty management. The company must exhibit all of its products and make an attempt to distinguish them from the competitors.

When there are several variants of the original product on the market, the product has attained its full potential. During this time period, the product is most profitable. In this last phase, it is typical for product sales to decline with the market. Before the decision to remove a product from the market, there are several questions that must be answered.

It is difficult to decide to remove a product from sale due to problems such as maintaining the device's functionality, assuring a sufficient supply of replacement components and forecasting how rivals would react to the market vacancy. Companies would often maintain a high price plan for diminishing products in order to increase their profit margin and ultimately alienate the few remaining loyal customers from buying the product. This phase can also be referred as the end-of-life phase.

1.3 DEVELOPMENT IN MICROELECTRONICS AND COMPUTER HARDWARE

The 19th century experienced an industrial revolution which considerably enhanced the physical power of human beings. In the 20th century there was another revolution when computers were introduced. These computers offered an enhancement of man's mental capabilities. Computers are now being widely used in all the engineering fields, and computers are essential to each significant engineering endeavour. Recent advancements in computer memory and processing power have made it possible to solve more difficult problems and do more computations in less time. More importantly, this has become possible due to developments in the field of ***microelectronics*** and integrated chips (IC). We are witnessing the phenomenon of ever-increasing chip density.

Due to very large scale integration (VLSI), the price of computer hardware has dropped dramatically, putting it within the financial grasp of most industrial companies. In addition, VLSI and Ultra

Large Scale Integration (ULSI) have contributed to the miniaturisation of computer components. Because of these advancements in computer science, CAD and CAM are quickly becoming the norm in the engineering industry. They can boost output because of this potential.

Now computers play an essential role in the product design and development processes. Computers have become a powerful tool for rapid and economic production of graphic pictures. CAE design and CAE are the advancement of CAD. These are fast evolving concepts that make use of computers and CAD in other fields of engineering like process planning, production, quality and maintenance, etc.

1.4 COMPUTER-AIDED DESIGN (CAD) DEFINED

A simple definition of CAD is the use of computers in the design process. CAD technologies are now commonly utilised in the design of engineering components, vehicles, aeroplanes, ships, spacecraft, buildings, textiles, machine tools, consumer goods and many other types of items. Tools for design analysis (such as finite element analysis and the finite element method), optimisation, testing, etc. are all a part of this suite. The field of CAD and CAM focuses on the use of computers in all stages of production, from the design office to the machine shops and assembly shops, from the inspection and quality control departments to the final components store. Conceptual design, analysis, rapid prototyping, component design, documentation, process planning and manufacturing are just few of the areas where CAD systems are being utilised extensively. CAD and CAM are two distinct areas that are combined in CAD/CAM. Over the course of the last 40 years, these two fields have grown separately. Nowadays, CAD/CAM systems include both of these methodologies. A CAD/CAM system enables a single system to be used for both the design and control of the production process.

In order to create and modify images on a display device with the assistance of a computer, a sophisticated approach known as interactive computer graphics is used as the foundation for CAD.

CAE is the practice of using computers to help in the engineering of a product in areas such as quality assurance, optimisation, analysis, manufacturability, etc.

VIDEO 2

1.5 DESIGN PROCESS

Let us now study the use of computers in design. Every product to be manufactured goes through two basic processes. These are

1. Design process,
2. Manufacturing process.

LO 3. To understand Design process and application of computers in design

First, the design is prepared by the design department. Then the machining operations, sequence of machining, tooling, etc. is decided by the process planning department. This information is sent to the machine shop to manufacture the components. After manufacturing and quality checks, the final product is marketed by the sales and marketing department.

1.5.1 Product Conceptualisation

Initially, the concept of design of the product starts emerging when the need is felt. Design conceptualisation does not have any laid-down procedures. It is the knowledge and experience of the engineers that help them in formulating the concept of a new product and its design.

1.5.2 Design Modelling and Simulation

In order to give final form to the concept of design, rough sketches or layouts of the product are drawn. This helps in giving a form to the concept by the engineers. This process is known as "***Design modelling and simulation***." These days advance CAD software such as IDEAS, Pro/E, Catia and SOLIDWORKS are available for product modelling and simulation.

Both product conceptualisation and design modelling and simulation are also called the "***synthesis process***" of design. Nowadays, due to the non-availability of engineers with vast experience, Artificial Intelligence and Expert systems are being developed which can help in the synthesis process.

1.5.3 Design Analysis

The design, once formulated, needs to be analysed for stress distribution using various theories such as theory of failure, bending stresses and torsion theory, etc. It is important to check that the maximum stress induced should be less than ultimate stress of the material, so that the product does not fail during its intended life. Design analysis can be simplified by using computers.

The Finite Element Method (FEM) is an advanced numerical analysis technique that is becoming popular for various types of analysis like stress analysis, thermal analysis, fluid flow analysis and acoustic analysis, etc. FEM software packages like Pro/MACHINICA, IDEAS, SIMULATION, NISA, ANSYS and NASTRAN are nowadays being used by CAD/CAM engineers for identifying stress distribution in machine components, buildings and bridges.

1.5.4 Design Optimisation

The term "optimised design" refers to a plan that has been finetuned to ensure maximum effectiveness under certain circumstances.

Various parameters are used to optimise the design process. Factors that can be taken into consideration are weight factors, cost factor, minimum deflection and maximum energy absorption, etc. The complexity in design optimisation increases with an increase in the number of constraints.

1.5.5 Design Evaluation

After the design optimisation process, the final design part is still not over, and the design is not communicated to the process planning or manufacturing departments unless it is tested. The design can be tested by two methods: Either by making a prototype of the ***product*** and then testing the prototype, but this is a time-consuming process; or the other method (which is much faster) makes use of concept called ***virtual manufacturing***. In this technique, a solid model of the component is prepared on some software package like IDEAS, Pro/E or Solid Edge and then it is subjected it to various types of testing by making use of the testing module in these packages.

1.5.6 Design Documentation and Communication

After the design evaluation stage, documentation of design is carried out by preparing drawings either manually or using a CAD package. Use of computers for drawings helps in systematic storage of the drawings and making suitable modifications as desired. CAD packages help in making the design process fast, accurate and easy.

1.5.7 Computer-Aided Process Planning

Process planning is a very important task carried out before the actual machining of the designed part. In this task, planning of all the machining operations is carried out. In this process, tooling

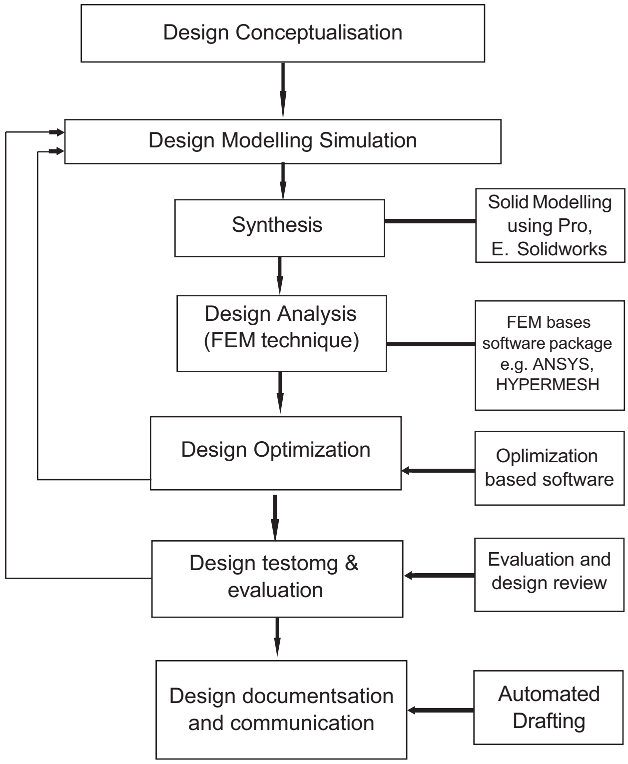

FIGURE 1.3 Computer application in design

and fixture planning of all the machines is decided. Process planning is carried out by highly experienced engineers. Nowadays ***computer-aided process planning*** (CAPP) is becoming popular due to availability of various CAPP software packages.

Manufacturing: Conventional machines, numerically controlled (NC) machines or computer numerically controlled (CNC) machines are used for machining when process planning is complete. Using computers has become an integral part of the design process, which is shown in the flowchart in Figure 1.3.

1.6 IMPORTANCE AND NECESSITY OF CAD

The importance and necessity of CAD has been recognised mainly due to following reasons:

1. Data collected throughout the design, process planning, production, analysis, etc. phases may all be stored and managed by a computer system.
2. Second, 3-D models allow for visual inspection and checking of complex geometric designs before real prototypes are made.
3. Use of CAD packages make design modelling and simulation an easy task.
4. Before putting a concept into action, it may be analysed and optimised using CAD/CAM software.
5. Using CAD to streamline the product design and development process shortens production times.
6. Effective use of CAD tools improves the productivity of the design processes. It enhances the capabilities of the design engineer in both quality and quantity. Development of interactive graphics software and versatile graphic facilities make simulation an easy task.

7. Design is an interactive process. The number of iterations to be performed depends on the complexity of the problem. Using CAD, it is simple to evaluate and compare many design options and then execute the one that works best.
8. A CAD system can be integrated with a CAM system. This means that CNC machines can receive CAD data in real time and use them to generate part programs for producing the components.

1.7 APPLICATIONS OF CAD

The applications of CAD in industry are enumerated below:

1. Developing solid models of various components and assemblies using CAD software packages,
2. Changing and enhancing component models,
3. Picking colours for 3-D models,
4. Seeing the object or its parts from various perspectives and cutaways,
5. Studying the product for its manufacturing planning, standardisation and simplification,
6. Performing an interference test on an assembly's mating components,
7. Analysis of mechanical parts, structures and bridges for stress,
8. Studying the product for material requirement, costing and value engineering,
9. Preparing detailed component drawings and assembly drawings,
10. Preparing a database for future reference and record.

Because of such user-friendly applications, CAD has been widely implemented in the automobile, aerospace, shipbuilding, machine tools consumer goods and other engineering industries.

1.8 COMPUTER-AIDED MANUFACTURING (CAM)

With the advancement of computer technology, computers have been implemented in almost every kind of industry including the manufacturing sector. One possible definition of "Computer-Aided Manufacturing" is "any computer-based assistance in the production of a specified product." Computers may play a direct role or indirect role in manufacturing a given product.

The direct role refers to computerised operation and control of a manufacturing process. For example, consider a lathe machine being operated by a computer. The computer can used to control the production equipment while making a component.

Several process variables may be tracked. In order to control the machining process, the computer may take appropriate action based on the machining requirements stored in its memory.

The indirect role of computers in manufacturing refers to:

1. Computer-aided process planning,
2. Computer-aided NC part programming,
3. Computer-aided material requirement planning and manufacturing planning,
4. Computer-aided material handling and storage,
5. Computer-aided inspection and quality control, etc.

1.9 COMPUTER-INTEGRATED MANUFACTURING (CIM)

CIM is an extension of CAD/CAM. It integrates a CAD/CAM system with the business functions of an organisation.

CIM aims at integration of:

1. Manufacturing tools like CAD/CAM, flexible manufacturing systems, robotics, materials requirement planning, group technology, just-in-time concept, production planning, capacity planning, inventory control, etc.,

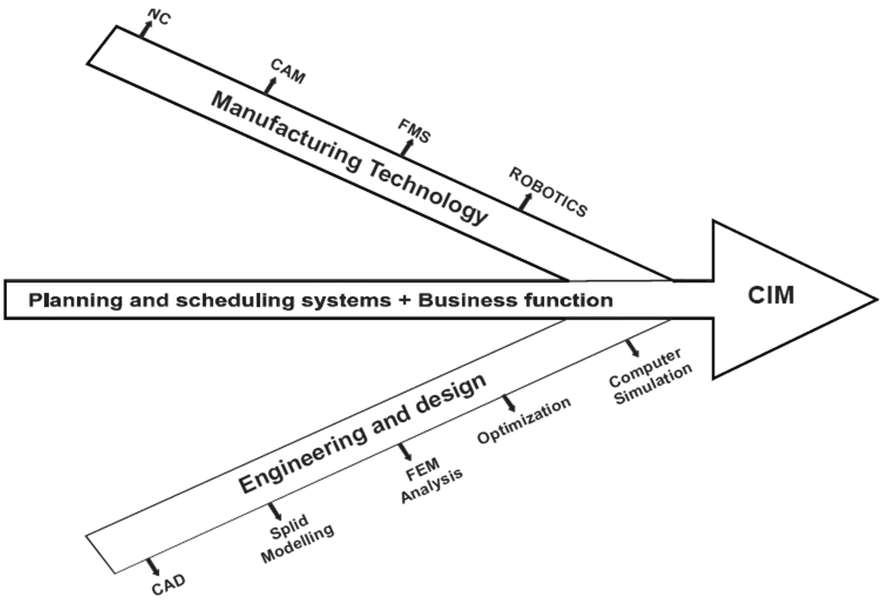

FIGURE 1.4 Integration of technical and business function in CIM

2. Other functional areas of organisation including marketing, purchase order control, vendors and personnel management, etc.,

Hence, all of CAD/technical CAM's features, plus all of the company's administrative tasks, are part of CIM (see Figure 1.4). From the moment an order is received all the way through the manufacturing process, including product design, production, marketing and shipping, computer technology is used as part of a CIM system. CIM is a broader concept than CAD/CAM since it encompasses the commercial operations of a company.

CAD and manufacturing (MM) is the focus of CIM. This field is focused on automating every step of the design and production processes with the help of computers. Distributed data processing, computer networks and database management systems all play significant roles in CIM's technological infrastructure.

1.10 COMPUTER FUNDAMENTALS

LO 4. To understand computer fundamentals

Any computer system consists of three main units. These are as follows:

1. Input devices,
2. Processing unit,
3. Output devices.

To interact with the CAD packages several input devices are used. These facilitate in feeding data or other input to the computer system. A keyboard, mouse, light pen, joystick, touch screen and digitiser are some of the input devices commonly used in CAD systems.

The processing device of a computer is called a central processing unit or CPU. A CPU is also considered to be the brain of the computer because all the processing of data is carried out there. The CPU consists of three components or subunits. These are:

1. Storage,
2. Arithmetic and logic unit,
3. Control unit.

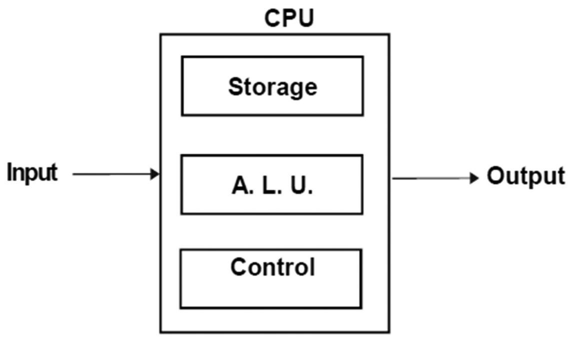

FIGURE 1.5 CPU components

The flow of information in a computer system is as shown in Figure 1.5

The capacity of the storage unit to store data is expressed in terms of bits. A bit is the unit of binary numbers, which are formed by 0 and 1 only, in various combinations. Computers can understand the language of binary numbers only. Hence it converts all the information and data into bits; 0 and 1 represent the status of electronic signals that are passed to and from a computer.

For example, **1101** is a binary number with 4 bits (it should not be confused with decimal number one thousand one hundred and one). A bit is a very small unit for storage, there are larger units for memory as follows:

1 byte = 8 bits,
1 kilobyte = 1024 bytes,
1 megabyte = 1024 kilobytes,
1 gigabyte = 1024 megabytes.

A computer system has two types of memory:

1. Main memory or Random Access Memory (RAM),
2. Secondary memory or Read Only Memory (ROM).

When the computer is switched off, RAM loses the data stored in it. ROM is permanent memory and retains data and information stored in it even after the computer is switched off. This data can be retrieved again and again.

A computer system is a combination of hardware and software. Hardware is defined as the physical unit of a computer that can be seen by the naked eye. Software may be defined as a link between the hardware and the user. Software is used to activate hardware in order to get the desired results.

There are two types of software. These are ***application software and system software***. The system software is developed by those with a detailed knowledge of hardware. Examples of such software are operating systems, like DOS, Windows, UNIX, LINUX, etc. The software on which a user works is called applications software. Application software interacts with system software which in turn interacts with the hardware.

The commonly used ***output devices*** for a CAD system are plotter, printer, copiers and camera systems. Different types of plotters available are flat bed plotter, drum plotter, and pinch roller plotter, etc. These may be either pen plotters or electrostatic plotters.

The different types of printers available are electrostatic printers, inkjet printers, laser printers, impact printer, thermal printers and line printers.

Let us study input and output devices used for computer graphics in more detail.

1.10.1 Input Devices

Information and commands are fed into the computer through input devices like keyboards and mice. A digital computer's input device takes whatever data or signal it receives as input and transforms it into the binary format the computer understands. Input is handled through a keyboard and a few switches. Physical quantities such as temperature, pressure, speed, location, etc. are measured and controlled using computers as well. For this, we use transducers, which are devices that take in measurements of the physical world and output electric impulses that are proportionate to those measurements.

1.10.1.1 Keyboard

Computer keyboards have descended from typewriters. A keyboard sends information to the CPU each time a key is pressed or released. Keyboards available on the market may have a variety of sizes and shapes but most keyboards have following types of keys in common:

1. Standard typewriter keys that are used to type text and other data,
2. Function keys labelled F1, F2, F3 and so on, also called programmable keys,
3. Special purpose keys such as Ctrl (Control), Del (Delete), Ins (Insert), Alt (Alternate), Caps Lock, Scroll Lock and Num Lock,
4. Cursor movement keys used to move the cursor on the screen. The keys have directional arrows on them,
5. Numeric keys are used to enter numbers for mathematical calculations.

The most common ***keyboard design*** uses a sheet of elastomeric substance (i.e., an artificial rubber) placed between keys and a printed circuit board. This rubber sheet has a dome shape in it directly beneath each key. When the key is pressed, it pushes down the dome which comes into contact with an electronic circuit board below. There is a conductive spot on the inside of each of the dome which completes the circuit on the printed circuit board, signalling to the CPU that the key has been pressed.

Computers that are intended for use in hazardous environments use keyboards that are often sealed. Such keyboards use a membrane or a simple capacitive switch. These keyboards have sensitive regions called keypads which when pushed generate signals for the CPU. Though these keyboards last longer in hostile environments the disadvantage is that you cannot type as quickly and accurately when compared to a regular one.

For those who are not good at typing, using a ***voice recognition*** system is an easy way out. This system converts spoken words into electrical signals by comparing the electrical pattern produced by the user's voice with a set of pre-recorded patterns.

1.10.1.2 Mouse

A mouse is a pointing device which when moved on a surface, generates digital signals that are sent to the CPU. These signals are used by the mouse program to control the location of the on-screen cursor. One of the mouse's buttons may be used to choose an item or file from the display.

An ***optomechanical mouse*** is most popular these days and is a hand-held device with a rubber ball protruding from the underside. Moving the mouse causes the ball to roll. This ball makes continuous contact with the x-roller and y-roller. When the rubber ball moves, it in turn rotates x- and y-rollers and optical encoders close to it generate signals to indicate the amount of motion in each of the two perpendicular directions. The disadvantage of such a mouse is that it tends to pick up dust as the ball rolls on a flat surface. This tends to damage the mechanism that converts that ball's rolling motion into x and y displacement signals. The mouse can be opened at the bottom to clean the dust accumulated inside the mouse. An *optomechanical mouse* is a hand-held device with a rubber ball protruding from the underside.

The problem has been eliminated in the optical mouse which is most popular these days. An LED is located underneath the mouse. It moves the cursor on basis of light reflected from a shiny flat surface beneath the mouse.

1.10.1.3 Graphics Digitiser Tablets

A graphics tablet is a flat, rectangular input device with a stylus shown in Figure 1.6. Each point on the tablet corresponds to a point on a PC's screen. The stylus is like a pen with a pressure switch in the tip. It may be cordless or connected to the tablet with a wire. As you move the stylus with its tip on the tablet, the cursor moves through the corresponding points on the screen. The digitiser tablet uses a technology in which a grid of wires is buried in the surface of the tablet. The tablet's electronic circuitry sends signals through these wires which are received by the stylus placed over tablet. The signal returned by the stylus to the tablet's electronic circuitry determines the point over which the stylus tip was positioned. Other technologies used by digitiser tablets are based on the sonic and magneto-secretive effects. The digitiser tablet is primarily used for tracing over existing drawings. Three dimensional tablets have also been developed to enter 3-D coordinates into a computer system.

1.10.1.4 Scanners

After the keyboard, mouse and digitiser tablet, a scanner is the most common input device.

Basically, they are classified into two types:

1. **Drum scanners (sheet fed scanners):**
   They can scan only flat sheets of paper or film.
2. **Flatbed scanners:**
   They can scan bulkier objects such as pages of a book.

Both charge-coupled device (CCD) and charge-independent pixel (CIS) are popular technologies used for creating scanners (contact image sensor). CCD scanners employ a moving mirror and focusing optics to project an image of whatever is on the scanner's window onto a linear array of light sensors. A bright light inside the scanner illuminates a band on the window that moves along the mirror's motion, thus permitting the scanner to read the contents of the document placed on the top of the window.

A contact image sensor is an array of light sensors that can be moved along with the linear light source on the underside of the scanner window and receive the reflected light from the document directly without using focusing optics. But the disadvantage of such scanners is that they have lower image quality and resolution compared to CCD scanners.

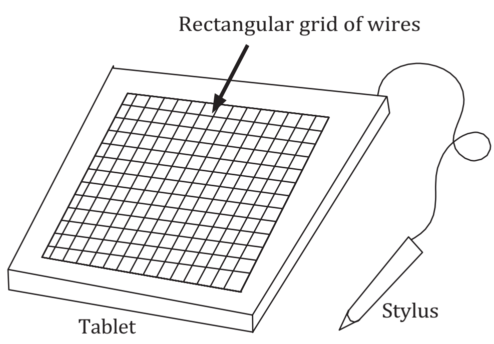

FIGURE 1.6 Tablets

Some other special purpose input devices popular these days are optical character readers, digital cameras and digital video cameras.

1.10.2 Output Devices

Whenever the computer processes data, it will transmit the results to the appropriate output. To regulate or activate machinery, an output device may either store data, print information or display information. Standard output devices include the following: Printers, CRTs, LEDs, digital to analog converters (D/A) converters, controllers, actuators, etc.

The most commonly used output devices in computers are monitor, printer and plotter.

1.10.2.1 Monitor

In almost all computers the information output is obtained primarily by means of video display, also called monitor or screen. The monitor consists of the hardware that actually creates the image you see and some electronic circuitry to activate the display. The monitor may be based on various technologies to display the image, for example, ***cathode ray tube*** (CRT), ***liquid crystal display*** (LCD) and ***plasma display***. In CRTs a beam of electrons is made to hit a phosphor-coated screen. The spot on the screen at which many electrons hit each microsecond will glow brightly.

1.10.2.2 Printer

After a monitor, a printer is the most common means of getting an output. Some of the printers used these days are enumerated as follows:

1.10.2.2.1 Impact Printers

These were the first to be developed. In these printers, a ribbon soaked with ink is positioned in front of piece of paper, then hit upon with a hammer bearing shape of some character. The impact drives ink out of ribbon onto the page. Character printers and dot matrix printers are the two main categories of impact printers. Dot matrix printers create an image by printing individual dots, whereas character printers utilise curved hammers to create a full sign or letter in a single stroke.

1.10.2.2.2 Inkjet Printers

These printers spray a liquid ink onto the page using multiple jets or nozzles aligned in the print head on a carriage that moves horizontally across the page. Each ink droplet is charged as it passes through a value. Then it passes through horizontal and vertical deflecting plates which direct the ink drops to the desired spot on the paper.

1.10.2.2.3 Laser Printers

These printers have a photosensitive transfer surface built in the form of a rigid cylinder of metal with a thin coating of the photoconductor on its outer surface. The photoconductive material acts as an insulator in the dark but as a good electrical conductor in presence of light. The photoconductive surface which is in a darkened space is charged to a high electrostatic potential. This charge is selectively drained off by shining light on to selected regions of the photoconductive surface.

The surface is flooded with toner particles (mixture of tiny, coloured material and plastic bond material). The toner particles stick only the portions carrying an electrostatic charge.

Paper with an opposite electric charge is pressed against the toner-coated photoconductive charge. Opposite electrostatic charges attract each other. The paper is then separated from the photoconductive surface and most of the toner comes along with the paper by electrostatic attraction. The toner-laden paper is heated to fuse ink particles to the paper.

1.10.2.3 Plotter

A plotter is a computer-driven output device used to make drawings. It has an automatic arm that holds a pen and can press the pen down against the sheet of paper or raise it up at the same time, moving in a prescribed manner. Commonly used plotters are a drum plotter, flat bed plotter and inkjet plotter.

A drum plotter has a long cylinder with a drawing sheet rolled over it, and a pen carriage. Under the computer's control, the drum rotates back and forth while the pen carriage moves horizontally along the cylinder axis to generate the desired drawing. A flat bed plotter uses a horizontal flat surface on which drawing sheet is fixed. The pen carriage and the flat bed under the computer control move along the x- and y-axes to generate the drawing. An inkjet plotter employs inkjets mounted on the carriage and the paper is placed on the drum. Ink of different colours may be used to produce multicoloured drawings. These are more reliable compared to pen plotters.

1.11 SUMMARY

- Rapid development in the field of computers has become possible due to developments in the field of microelectronics and integrated chips.
- CAD can be defined as use of computers to aid the design process.
- CAD and CAM originally developed independently but have now been integrated into CAD/CAM systems.
- CAE can be defined as an engineering philosophy which brings together all the engineering activities such as computer simulation, computer aided analysis and optimisation, CAD, computer-aided drawing, computer-aided process planning, computer-assisted production management, computer-aided manufacturing and numerical control, CAD and computer-aided drafting.
- Design process involves the following steps: Product conceptualisation, design modelling and simulation, design analysis, design optimisation, design evaluation, design documentation and communication.
- The importance of CAD can be realised from the fact that computers can store large amounts of engineering data, create complex geometrical shapes, perform modelling and simulation, etc.
- CIM includes all the engineering functions of CAD/CAM as well as business functions such as order entry, payroll and accounting, customer billing, etc.
- Common input devices used for CAD are keyboard, mouse, light pen, joystick, touch screen and digitisers, etc.
- Common output devices used for CAD are monitor, printer, plotter, etc.
- Auto CAD, Pro/E, CATIA, Solid Edge, SOLIDWORKS and NISA are some of the commonly used CAD packages.

1.12 EXERCISE

1. What do you understand by computer-aided design? Discuss reasons for implement CAD in industry (BT level 2).
2. What are different phases of product development cycle (BT level 1)?
3. Describe various stages in design and development of a piston. How can CAD be used to accelerate the development process (BT level 2)?
4. Give specific advantages of using CAD in product development cycle (BT level 2).
5. Discuss the statement "CAD is only a tool in the design process" (BT level 2).
6. Define the term, "computer-aided engineering" (CAE) (BT level 1).
7. Suppose you are a design engineer in a CNC cylindrical grinding machine manufacturing company. How will you implement CAD in your company? How will you use CAD to improve your design productivity (BT level 4)?
8. What do you mean by computer hardware and software? What are the input and output devices used for CAD? Name some important CAD software popular in design and development industry (BT level 1).

9. Why is the application of computers in the engineering industry becoming so popular? Name a few areas in which CAD is being widely used in industry (BT level 2).
10. What should be the qualities of a CAD engineer? (BT Level 1).
11. Differentiate between classical design and CAD procedures (BT level 4).
12. Explain the functions of basic hardware components of a general-purpose digital computer (BT level 2).
13. Describe design related tasks which are performed by a modern CAD system (BT level 2).
14. What are the benefits of CAD (BT level 1)?
19. Make a table of important design phases. What are the CAD tools to support various design phases (BT level 2)?
20. What do you understand by computer memory? Name two types of computer memory (BT level 2).

1.13 MULTIPLE-CHOICE QUESTIONS

1. What is the primary purpose of CAE software?
   a. To create 3-D models of products.
   b. To simulate and analyse product designs.
   c. To generate engineering drawings and specifications.
   d. To optimise production processes.
2. Which of the following is not a common feature of CAE software?
   a. Pre-processing tools for model setup.
   b. Solver engines for performing calculations.
   c. Post-processing tools for interpreting results.
   d. Design optimisation tools for generating CAD models.
3. Which of the following is a common application of CAE software?
   a. Creating marketing materials for products.
   b. Generating 2-D drawings for product manufacturing.
   c. Simulating the behaviour of structures under load.
   d. Designing user interfaces for software applications.
4. What is the primary goal of Product Lifecycle Management (PLM)?
   a. To manage product costs throughout the product lifecycle.
   b. To optimise product design and development.
   c. To increase product profitability.
   d. To manage product information and data throughout the product lifecycle.
5. Which of the following is not a benefit of implementing a PLM system?
   a. Improved collaboration and communication among team members.
   b. Reduced product development time and costs.
   c. Increased risk of product failure or recall.
   d. Improved quality and reliability of products.
6. What does CAD stand for?
   a. Computer-Aided Drawing.
   b. Computer-Aided Design.
   c. Computer-Assisted Drafting.
   d. Computer-Assisted Design.
7. What is the primary purpose of CAD software?
   a. To create 2-D and 3-D models of products.
   b. To simulate and analyse product designs.
   c. To generate engineering drawings and specifications.
   d. To optimise production processes.

8. Which of the following is not a common feature of CAD software?
   a. Drawing tools for creating 2-D geometry.
   b. Modelling tools for creating 3-D geometry.
   c. Simulation tools for analysing product designs.
   d. Manufacturing tools for producing products.
9. Which of the following is a common application of CAD software?
   a. Creating marketing materials for products.
   b. Generating 2-D drawings for product manufacturing.
   c. Simulating the behaviour of structures under load.
   d. Designing user interfaces for software applications.
10. Which of the following is not a benefit of using CAD software for product design?
    a. Improved accuracy and precision of product designs.
    b. Reduced product development time and costs.
    c. Increased manual labour required in the product design process.
    d. Improved collaboration and communication among team members.
11. What does CAM stand for?
    a. Computer-Aided Management.
    b. Computer-Aided Manufacturing.
    c. Computer-Assisted Machining.
    d. Computer-Assisted Modelling.
12. What is the primary purpose of CAM software?
    a. To create 2-D and 3-D models of products.
    b. To simulate and analyse product designs.
    c. To generate engineering drawings and specifications.
    d. To control manufacturing processes and machinery.
13. What does CIM stand for?
    a. Computer-Integrated Manufacturing.
    b. Computer-Implemented Machining.
    c. Computer-Influenced Modelling.
    d. Computer-Integrated Modelling.
14. Which of the following is not a common feature of CAM software?
    a. Tool path generation for machining operations.
    b. CNC machine simulation for verifying programs.
    c. Design optimisation tools for generating CAD models
    d. Post-processing tools for generating G-code.
15. Which of the following is a common application of CIM?
    a. Controlling manufacturing processes and machinery.
    b. Creating marketing materials for products.
    c. Simulating the behaviour of structures under load.
    d. Designing user interfaces for software applications.

Answers

1. Answer: b. To simulate and analyse product designs.
2. Answer: d. Design optimisation tools for generating CAD models.
3. Answer: c. Simulating the behaviour of structures under load.
4. Answer: d. To manage product information and data throughout the product lifecycle.
5. Answer: c. Increased risk of product failure or recall.
6. Answer: b. Computer-Aided Design
7. Answer: a. To create 2-D and 3-D models of products.

8. Answer: c. Simulation tools for analysing product designs.
9. Answer: b. Generating 2-D drawings for product manufacturing.
10. Answer: c. Increased manual labour required in the product design process.
11. Answer: b. Computer-Aided Manufacturing.
12. Answer: d. To control manufacturing processes and machinery.
13. Answer: a. Computer-Integrated Manufacturing.
14. Answer: c. Design optimisation tools for generating CAD models.
15. Answer: a. Controlling manufacturing processes and machinery.

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