Design and Applied Technology

Secondary 4 – 6

[Learning and Teaching Resources]

Simplified Version

Elective Module 5

Visualisation and Computer-aided Design (CAD) Modelling

Resource Materials Series
In Support of the Design and Applied Technology Curriculum
(S4 – 6)

Technology Education Section
Curriculum Development Institute
Education Bureau
The Government of the HKSAR

Preface

The Simplified Learning and Teaching Resources is edited by Mr. LAM Chi Lap, the retired panel head of technological subjects, based on the learning and teaching resources established by the Institute of Professional Education And Knowledge (PEAK), Vocational Training Council in 2009.

Teachers should read the "EDB S4-6 Design and Applied Technology – Learning and Teaching Resources: User Guide" before using the learning and teaching resources.

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Chapter 1 Product Visualisation and 3D Modelling

1.1 Visual Impact of Graphics

Visual representation plays an important role in product design and development.

Drawing is one of the major aspects in visual representation.

It has three major uses:

(a) Improving perception

(b) Planning projects

(c) Making finished art works

Figure 1.01 Drawing can make finished art works

Rendering includes the steps of creating, shading and texturing an object. Visual presentation can be enhanced by means of light-and-shadow and the surface properties of the objects concerned.

(a) Thick and thin lines

(b) Shading

(c) Highlighting

(d) Colouring

1.1.1 Thick and thin lines technique

In this technique, lines of different weights communicate different meanings and facilitate the understanding of the objects concerned.

The drawing on the right uses a thick line to indicate the boundary of a hidden surface, while a thin one represents two adjoining surfaces.

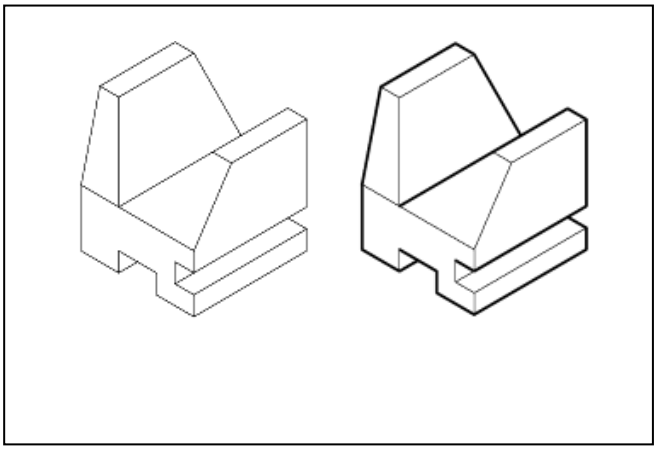


Figure 1.02 Drawing an object with different line weights

1.1.2 Shading

An appropriate level of darkness is applied by means of light and shadows to provide a feeling of depth.

(a) Line shading

(i) Using different line weights and densities to represent the light and shadows of an object;

(ii) Enhancing the light surface of an object with low-density lines;

(iii) Enhancing the object layering with lines of different densities.

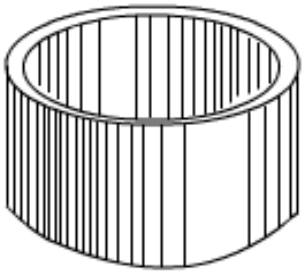


Figure 1.03 The light surface of a cylinder is highlighted with low line density

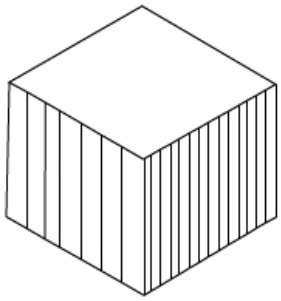


Figure 1.04 A cube drawn with lines of different densities

(b) Tone shading

(i) Illustrating shading in an object with back edge lines and white highlights;

(ii) Showing the light and shadow of an object with light sources from different positions;

(iii) Enhancing the tone shading by means of the same colour with different brightness.

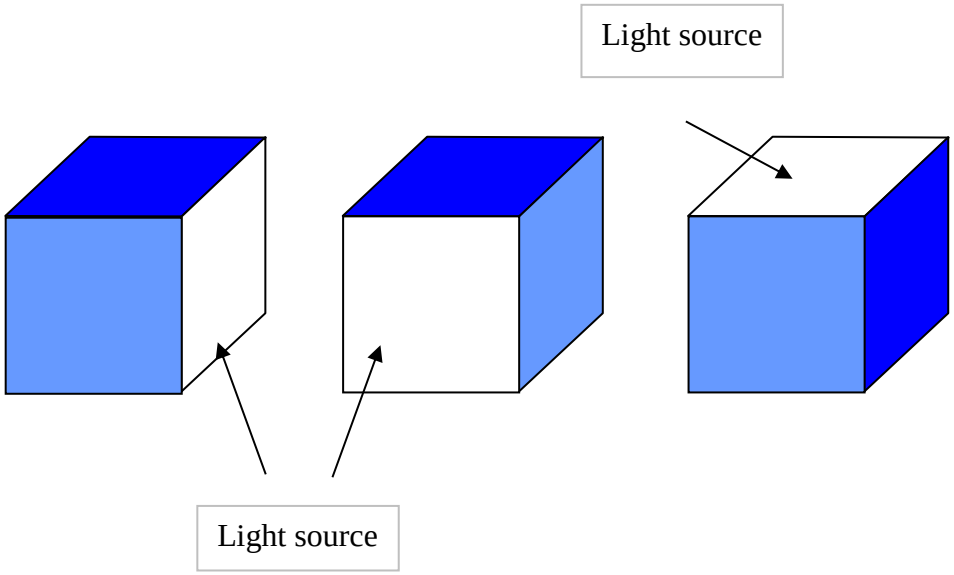


Figure 1.05 Light sources from different positions give different shading effects on the same object

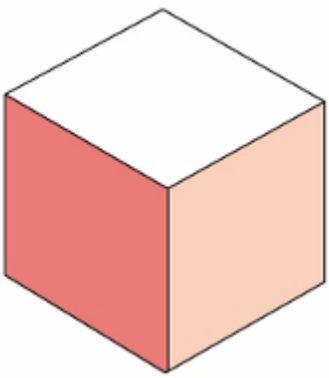


Figure 1.06 White for one side, and the same colour with different shades for the rest two

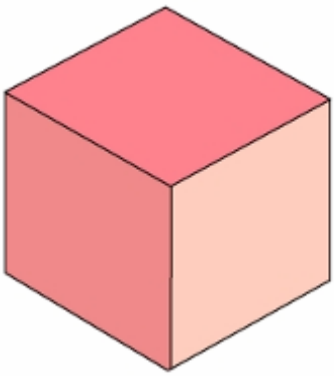


Figure 1.07 The same colour for all the three sides with different shades

1.1.3 Highlighting

"Highlight" refers to the area of an object that is directly illuminated by a light source. The light may have different effects when it falls on different surfaces of the object.

(a) Light reflected from a hard and polished curving surface is represented in white.

(b) Light reflected from a soft, dull and flat surface may be represented with light colour.

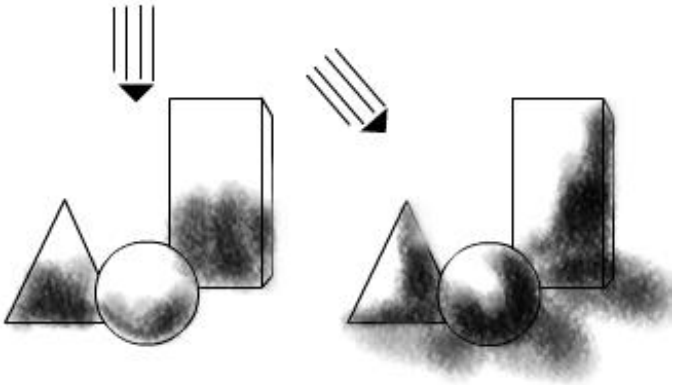


Figure 1.08 Highlight effects depend on the position of the light source

1.1.4 Colouring

"Colouring" is an important technique for object visualisation. There are "cool colours" and "warm colours".

(a) Cool colours, which contain a large amount of blue, such as blue, violet and green, give a calm, dull and gloomy-day impression.

(b) Warm colours, which contain a large amount of yellow, such as yellow, red and orange, give an energetic, comfortable and daylight impression.

Warm **Cool**

Figure 1.09 Colour spectrum of cool and warm colours

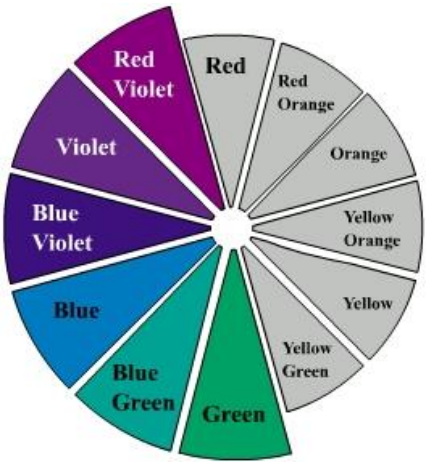


Figure 1.10 Cool colours on the left of colour wheel

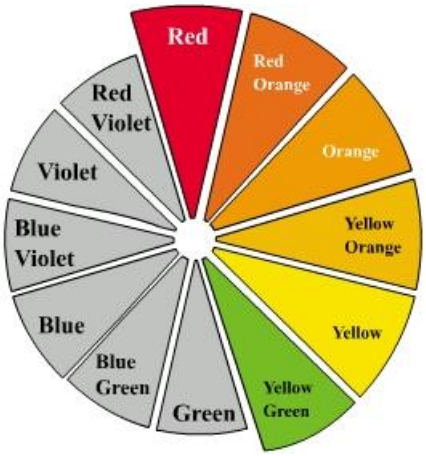


Figure 1.11 Warm colours on the right of colour wheel

Some common colouring materials for design are listed as follows:

(a) Markers – Pens with a thick point

(b) Colour pencils – Pencils for drawing fine colour lines

(c) Poster colours – Water-based paints in opaque colours

Figure 1.12 Markers

Figure 1.13 Colour pencils

Figure 1.14 Poster colours

1.2 3D Modelling Concepts

1.2.1 Limitations of graphical presentation

Presenting a 3D object on a 2D medium, such as a piece of paper or a computer monitor, may encounter limitations, and cannot easily replace physical modelling.

1.2.2 Physical models

A physical (3D) model is used to represent the real shape of an object, as small as a bolt, or as large as the solar system.

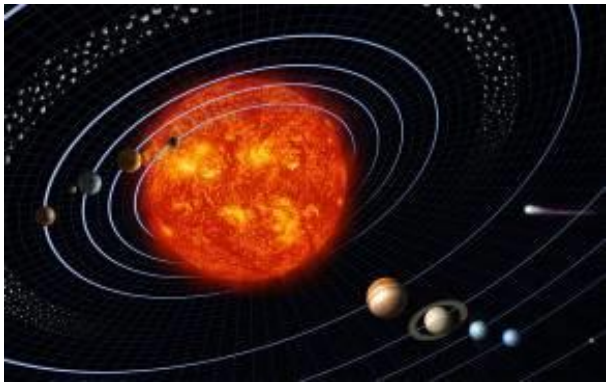


Figure 1.15 Examples of physical (3D) models

A model and the object it represents are only different in their sizes or scales. In such cases, the scale is considered an important characteristic.

A physical model is intended to facilitate the detailed visualisation of the:

(a) Internal relationship within the structure; or

(b) External relationship of the structure to the environment.

A physical model on a smaller scale can be used for different purposes, such as:

(a) For a better overview of the object it represents;

(b) For testing

(c) For a hobby

A physical model on a larger scale is generally used to enlarge a microscopic object, such as an insect or a molecule.

Physical models are sometimes better than floor plans. For example, a globe presents a view which cannot be expressed by a flat world map.

Examples of physical models

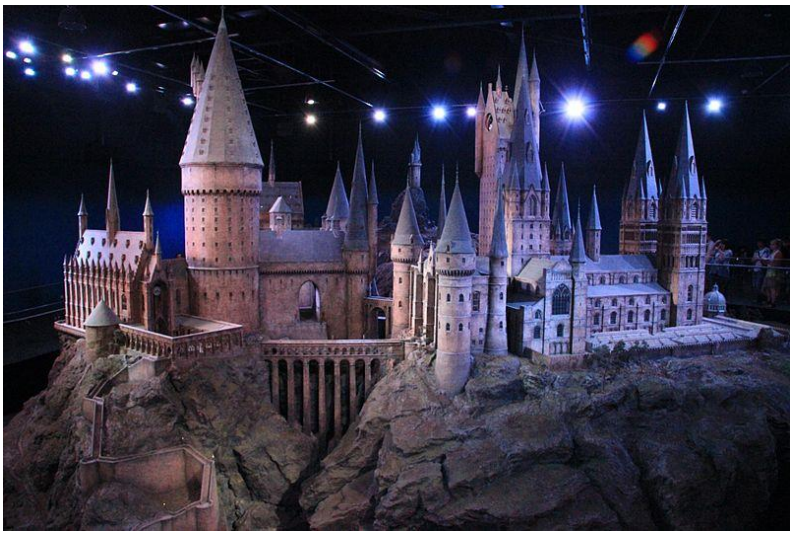


Figure 1.16 A 1:24 meticulous model for filmmaking

Figure 1.17 An animated robot model with a scale of 1: 1 (i.e., Actual size)

1.2.3 Selection of materials

Materials commonly used for making simple models are listed as follows:

Material	General characteristics
Acrylic	(a) Easy to bend when softened (b) Easy to cut
Cardboard	(a) Soft and thin (b) Easy to cut (c) Easy to glue together
Foam board	(a) Soft (b) Easy to cut

For models that are to bear certain loads or to undergo testing, commonly used materials are listed as follows:

Type	Material	General characteristics
Wood	Plywood	(a) Made of wood veneer (b) Commonly used for ordinary furniture
	Chipboard	(a) Similar to plywood (b) Made of wood chips and saw dust
	Medium density fibreboard (MDF)	(a) Similar to plywood (b) Made of softwood fibres
Plastics	Acrylic	(a) Easy to bend when softened (b) Easy to cut
	High-density foam board (HDF/HDFB)	(a) Strong, stiff and resilient (b) Commonly used for mattresses
Metal	Aluminium	(a) Silvery surface (b) Perfect machineability (c) Limited weldability
	Copper	(a) Yellowish (b) Low friction and suitable for making bearings
	Steel	(a) A commonly used metal (b) Good machineability (c) Good weldability

- Cardboard is often less than 2-mm thick and is mainly used to make folding cartons, set-up boxes and paperboard packaging.

Figure 1.18 Egg carton

Figure 1.19 Milk carton

- Corrugated fibreboard consists of a fluted corrugated sheet and one or two flat linerboards. It is mainly used for packaging and shipping products.

Figure 1.20 Corrugated fibreboard

Figure 1.21 Packaging carton box

- Plywood is manufactured from thin layers of wood veneer. “Plies” are stacked one on top of another and glued together with strong adhesives under pressure and heat to form the finished product.
- Compared with plain wood, plywood has greater strength and better resistance to cracking, shrinkage and twisting.

Figure 1.22 Plywood

- Chipboard is a type of fibreboard made of wood chips that are larger than those in the medium-density fibreboard and the hardboard.

Figure 1.23 Chipboard

- Medium density fibreboard (MDF or MDFB) is made from softwood fibres, wax and resin pressed under a high temperature. It is similar to plywood in terms of applications.

Figure 1.24 Medium density fibreboard

- Styrofoam board is lightweight and typically 5mm to 200mm thick. It can be used for display boards, poster boards and architecture models, among other things.

Figure 1.25 Foam board

Figure 1.26 High-density foam board

- High-density foam board is a stiff, resilient and lightweight material. There are different thicknesses and colours.
- Acrylic plastic (polymethyl methacrylate) is commonly used for fish tanks, laser discs, lenses, motorcycle helmets, etc.

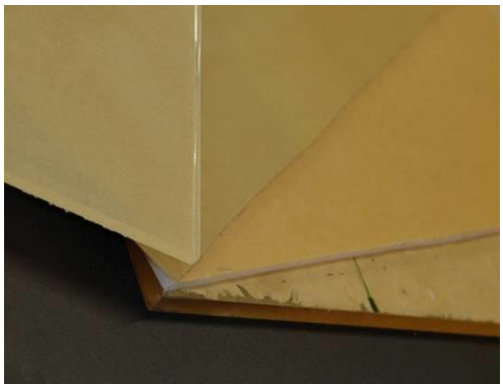


Figure 1.27 Acrylic plastic

Alloys that are commonly used for making physical models include:

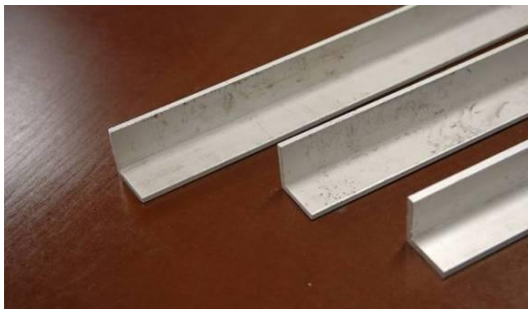
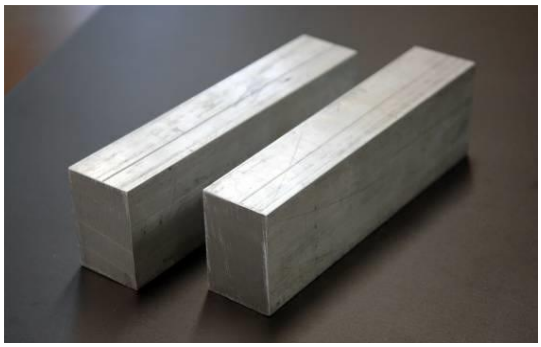
(a) Aluminium alloys

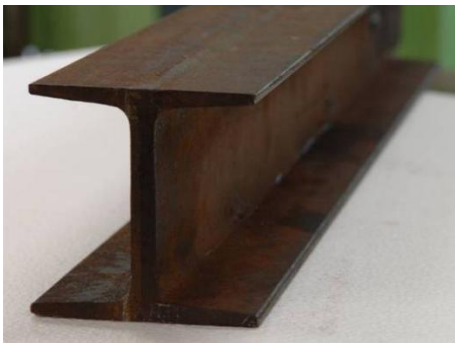
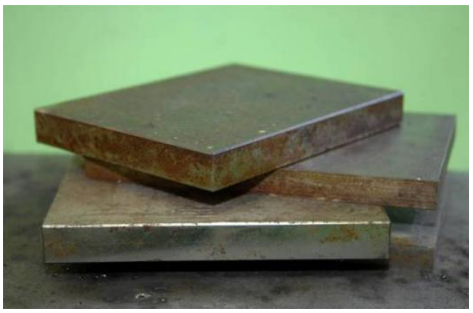
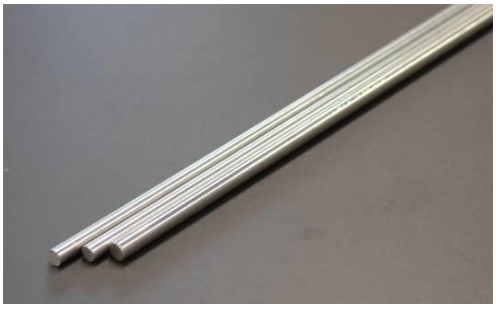
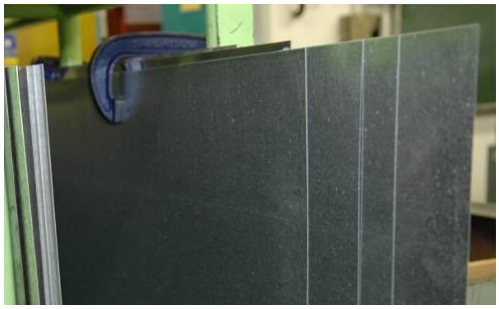
(b) Copper alloys

(c) Steel

(d) Zinc alloys

Alloys can be manufactured into the following forms:

Angle (Commonly known as “angle iron”, but not necessarily made of iron)	
Block	
Flat bar	

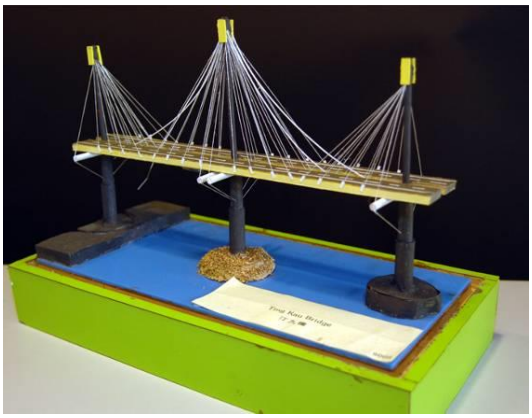
I-beam (Commonly known as “double-T iron”, but not necessarily made of iron)	
Plate	
Rod	
Sheet	
Tube	

Universal section	
Wire	

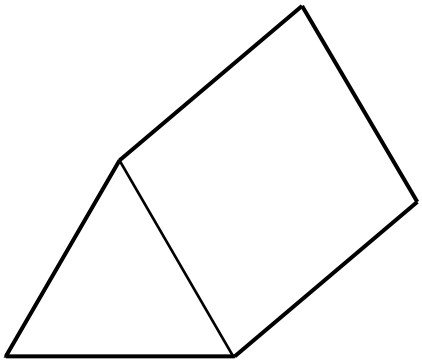
1.2.4 Simple tools and fabrication techniques

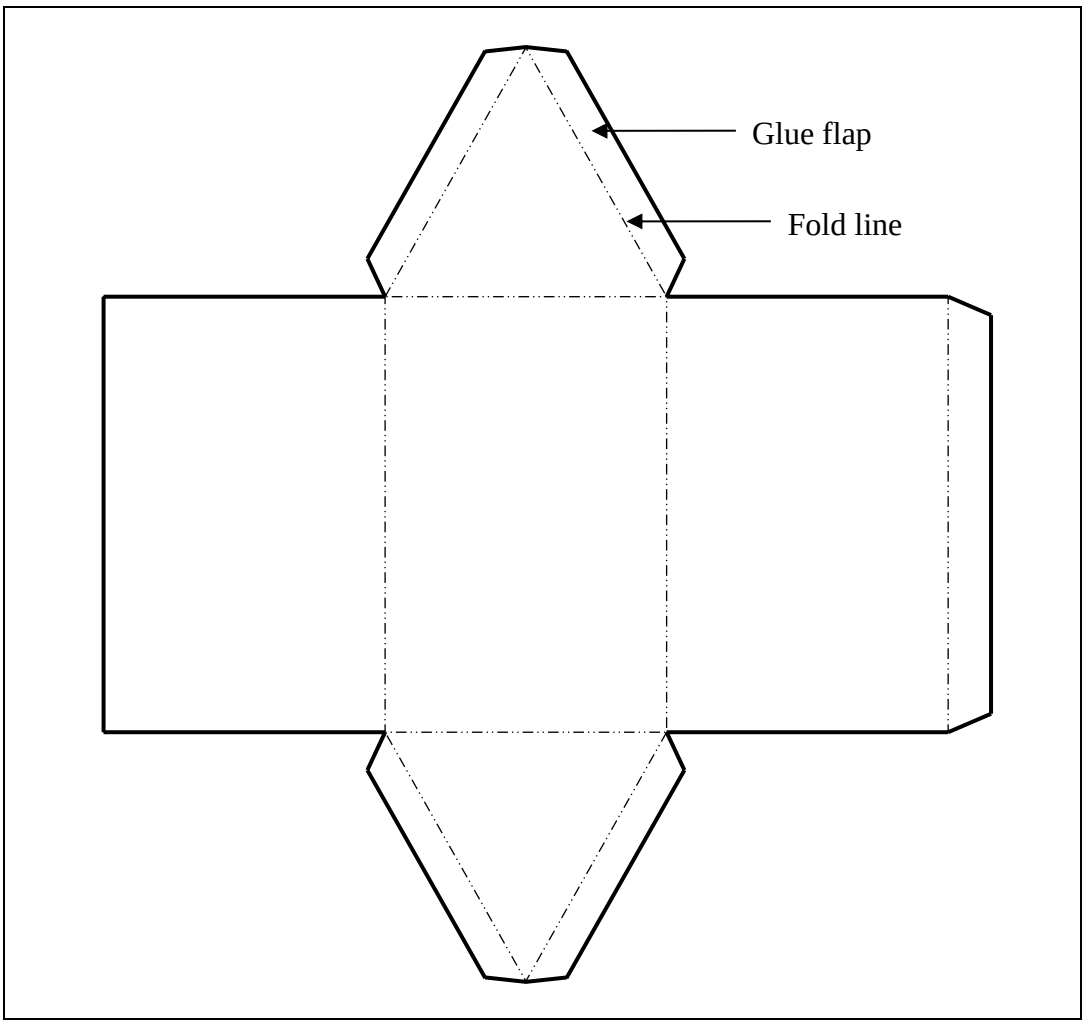
This section introduces some common tools for cutting and bonding cardboard, timber, foam board and acrylic plastic.

Common tools for cardboard models	
Procedure	**Tool**
Marking	Ruler
	Pencil
	Marker
Cutting	Scissors
	Utility knife
Joining	All purpose adhesive
	White glue

Examples of cardboard models	
	

Surface Developments
The development of surface of an object means the unrolling and unfolding of all surfaces of the object on a plane. It is commonly used to create 3D objects from cardboard. Every line on the development should show the true length of the corresponding line on the surface which is developed.

Example of the development of a triangular prism




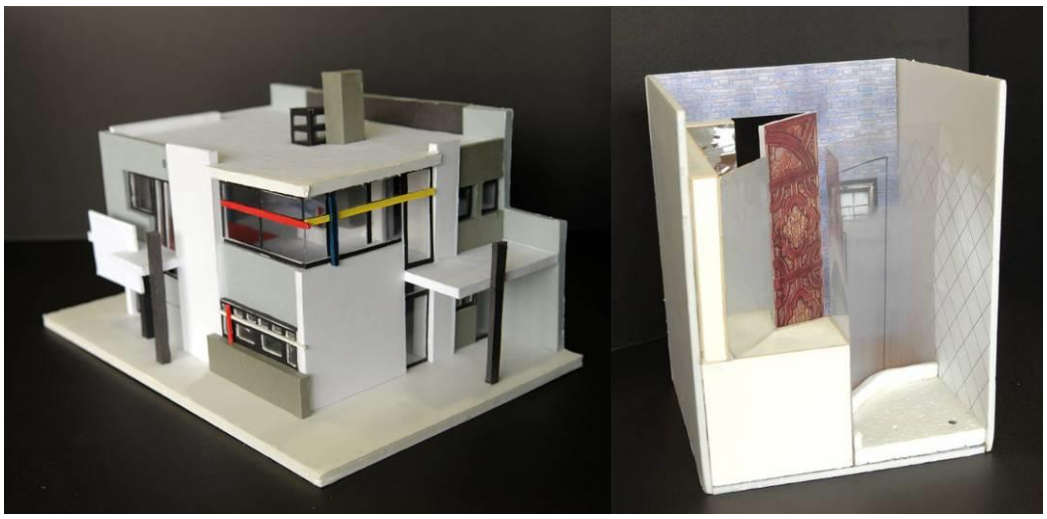
Common tools for wooden models	
Procedure	**Tool**
Marking	Measuring tape
	Ruler
	Pencil
Cutting	Hack saw
	Piercing Saw
	Coping Saw
	Drilling machine
	Electric hand drill
Joining	White glue
	Hammer
	Nail
	Self-tapping screw

Examples of wooden models

Common tools for foam board models

Procedure	Tool
Marking	Ruler
	Marker
Cutting	Utility knife
	Hot wire cutter
Joining	White glue

Examples of foam board models



Common tools for acrylic plastic models	
Procedure	**Tool**
Marking	Measuring tape
	Ruler
	Pencil
Cutting	Plastic-cutter
	Hack saw
	Piercing Saw
	Coping Saw
	Electric hand drill
Forming	Acrylic heater (strip heater)
Joining	Acrylic glue
	Hot glue

Technique of cutting an acrylic sheet

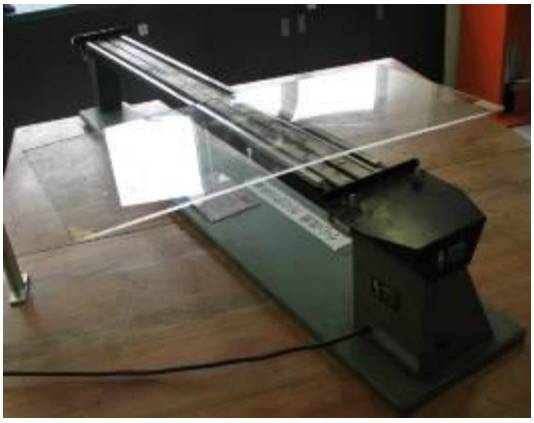
Draw the plastic cutter along a straight edge, such as a steel ruler.

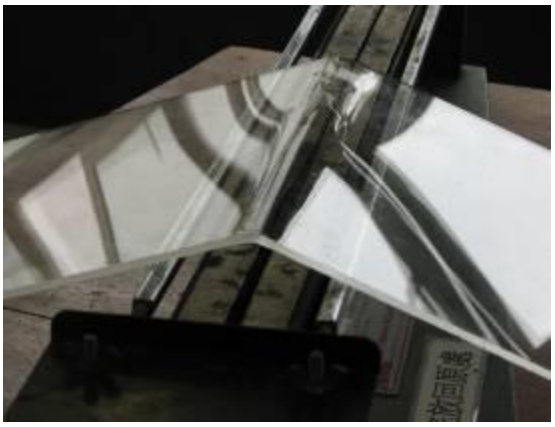
Align the cutting mark on the sheet with the edge of a table. Bend the sheet over the edge.

Examples of acrylic sheet models

Technique of bending an acrylic sheet

Turn on the heater





Place the acrylic sheet on top of the heater until it softens

Bend the sheet to the desired shape

Common tools for metal models	
Procedure	Tool
Marking	Bench vice
	Tough grip
	Steel ruler and scriber
	Try square
Cutting	Snips
	Drilling machine
Joining	Pop rivet
	Bolt and nut

An example of metal models (building crane)

1.2.5 Comparison of visual and physical models

For the demonstration of product designs, visual and physical models have different effects and limitations.

Aspect	Visual model	Physical model
Effects	Singular illustration of the plane image of the design	Comprehensive illustration of the 3D image of the design
Communication of information	Lower extent; imagination is required	Higher extent; closer to reality
Tools and materials used	Fewer and simple	More and complicated
Production	Easy, less time-consuming, more affordable	Difficult, more time-consuming, more expensive
Storage	Requiring less space; possible to be stored and managed in large quantities by means of computer	Requiring more space; difficult to be stored and managed
Delivery	Easy; possible to be delivered electronically	Difficult; must be shipped

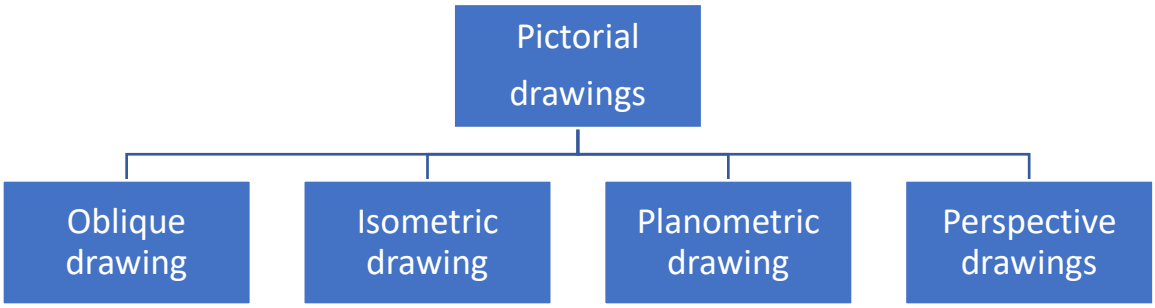
- At the early stages of product development, it is often necessary to conceptualise and provide a large number of new designs. Visual models are normally used at such stages since they are easier to make.
- At the later stages of product development, it is usually necessary to fully illustrate all aspects of the design for production planning. Physical models are generally used at such stages since they are more comprehensive.

Know More About Technology - 3D Printing Pen

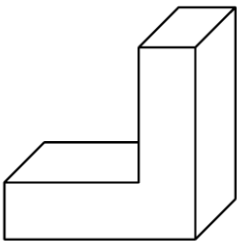
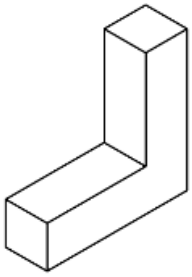
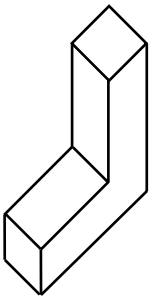
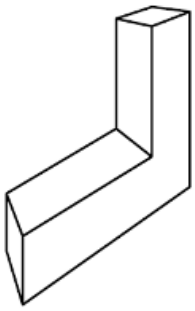
Chapter 2 Technical Visualisation

2.1 Pictorial Drawings

A pictorial drawing indicates the height, width and depth of a 3D object on a plane figure. There are many types of pictorial drawings, for example:



Categories of pictorial drawings

 Oblique drawing	 Isometric drawing
 Planometric drawing	 Perspective drawings

Among them, perspective drawings look the most like photographs.

2.1.1 Perspective drawings

- For a perspective drawing, it is assumed that viewer sees an object from a distance. The object is then scaled relative to the viewer based on the assumed distance.
- A perspective drawing consists of lines and vanishing points (VPs). A VP acts as the eyes of a viewer who is observing an object.

There are three types of perspective drawings, namely:

(a) One-point perspective (b)Two-point perspective (c) Three-point perspective

Figure 2.01 Three concrete buildings shown with three different types of perspective drawing techniques

(a) One-point perspective

- There is only one VP for a one-point perspective drawing. This perspective joins all lines towards that single VP. It is typically used in interior design drawings and window displays drawings.

Figure 2.02 Interior design graphic

Figure 2.03 Window display drawings

(1) **Station point (SP)**: It indicates the position of the viewer's eye.

(2) **Centre line of vision (CLV)**: It is a vertical line extending from the viewer's eye to the centre of the object.

(3) **Vanishing point (VP)**: It is the point where all the perspective lines from an object converge.

(4) **Eye level line (ELL)**: It is an infinite horizontal line always at the viewer's eye level.

(5) **Picture plane (PP)**: It is the plane onto which the perspective is projected.

(6) **Ground line (GL)**: It is an infinite horizontal line parallel to the horizon from which vertical measurements are made.

(b) Two-point perspective

- There are two VPs for a two-point perspective drawing. It shows the depth and space of an object more practically and accurately.
- Two-point perspective drawings are typically used in architectural design and daily life.

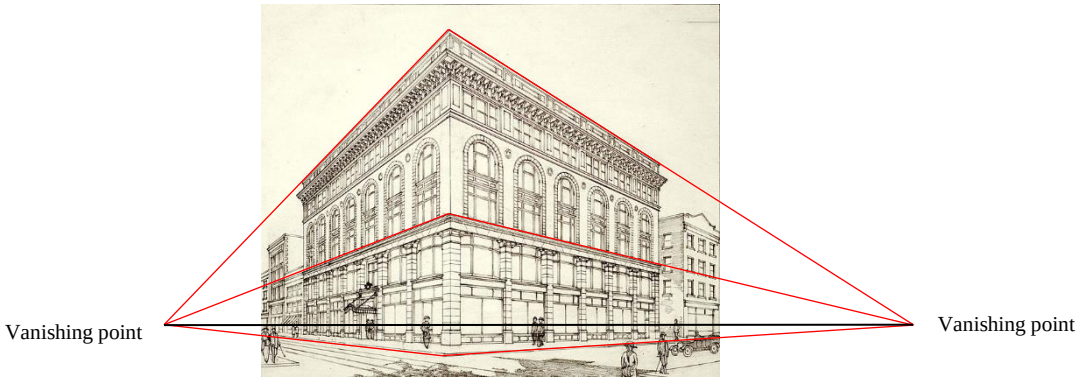


Figure 2.04 A two-point perspective drawing in architectural design

(c) Three-point perspective

In the three-point perspective there are three VPs, including two at the eye level and a third at the vertical position.

Three-point perspective is often used for viewing buildings from above or below, such as looking up at a skyscraper.

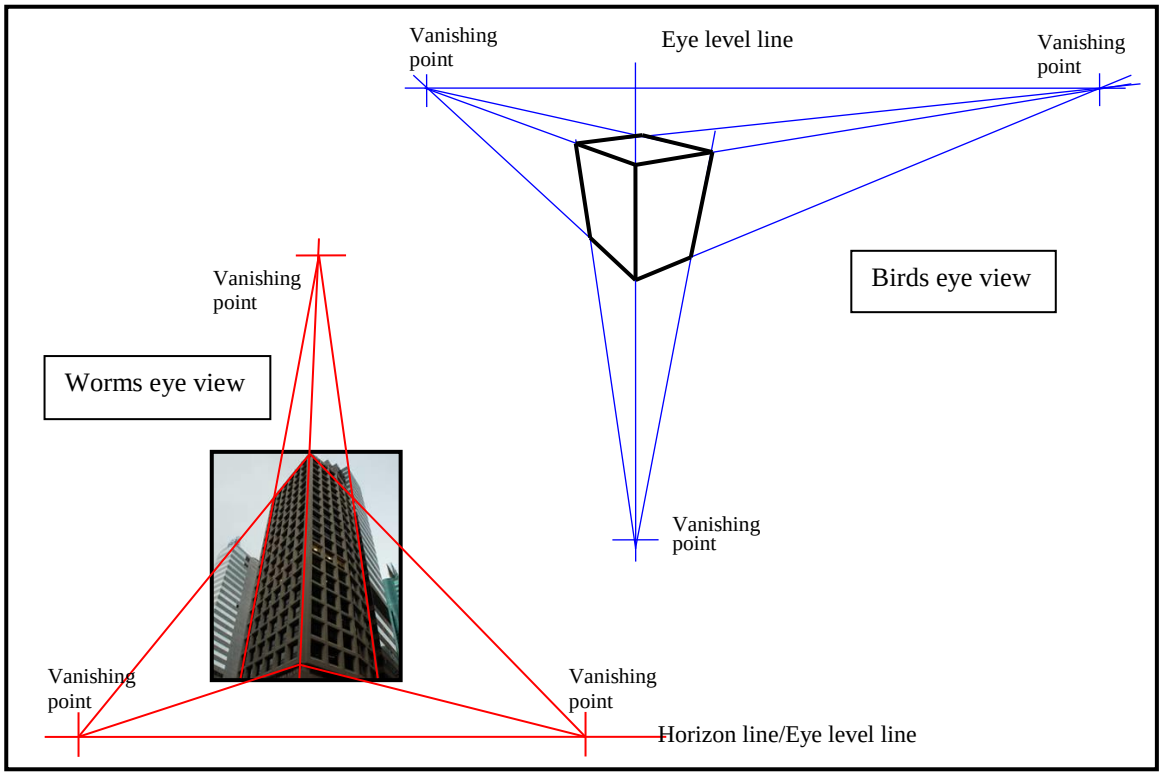


Figure 2.05 Three-point perspective of a building

2.2 Engineering Drawings

- An engineering drawing is to represent an object on paper graphically, including its shape, size and position.
- It is also known as a "blueprint". The object can be as small as a pin, or as large as a building.
- Engineering drawings are commonly used in various engineering sectors, such as architecture, civil engineering, electricity, electronics, manufacturing and mechanics.

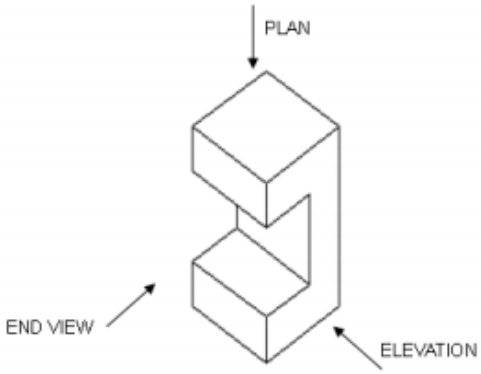


Figure 2.06 Observing a 3D object from three different directions

2.2.1 Drawing format

The two most common specifications for engineering drawings are as follows:

(a) Line specifications

(b) Dimensioning rules

Shape	Description	Functions
	Continuous (wide)	Visible line
	Continuous (narrow)	Dimension line, projection line, section line, drawing line
	Dashed (narrow)	Hidden line
	Long-dashed dotted (narrow)	Centre line
	Long-dashed dotted (narrow), wide at ends	Cutting plane

2.2.2 Orthographic projection

- For orthographic projection, an object is observed from three different directions (front, side, and top) and then all the views are projected onto a paper.
- Several plane drawings are used to represent a 3D object.

There are three common views in orthographic projection, namely:

(a) Elevation – What the viewer sees from the front;

(b) Plan – What the viewer sees from the top; and

(c) End view – What the viewer sees from the left or the right

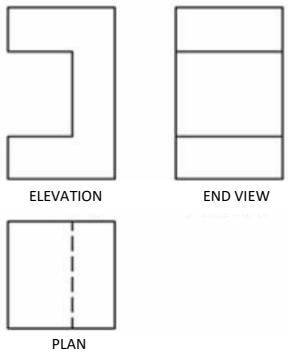


Figure 2.07 Presenting three orthographic views in one drawing

There are two schemes of orthographic projection, each with unique symbols:

(a) First Angle Projection (more popular in European countries)

(b) Third Angle Projection (more popular in the United States)

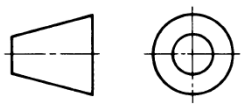


Figure 2.08 First Angle Projection symbols

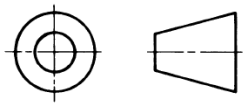


Figure 2.09 Third Angle Projection symbols

(a) First Angle Projection

- The vertical and the horizontal planes of the orthogonal projection intersect each other and produce four quadrants or angles as shown in the figure.

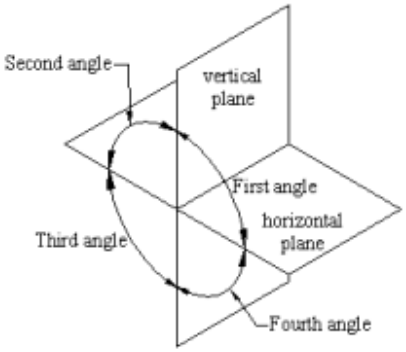


Figure 2.10 The four quadrants of an orthographic projection

The First Angle Projection method assumes that the object is placed in the first quadrant (first angle) and then projected (with parallel lines extended) to the horizontal, vertical and auxiliary vertical planes.

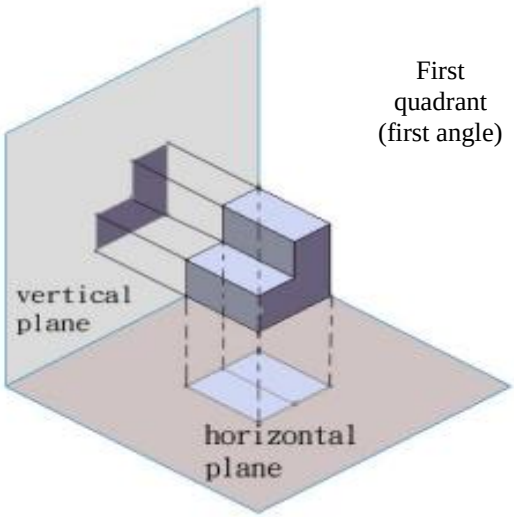


Figure 2.11 Orthographic projection of an object onto the horizontal and vertical planes

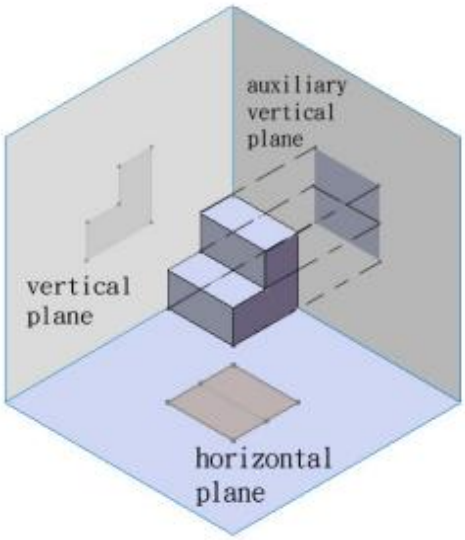


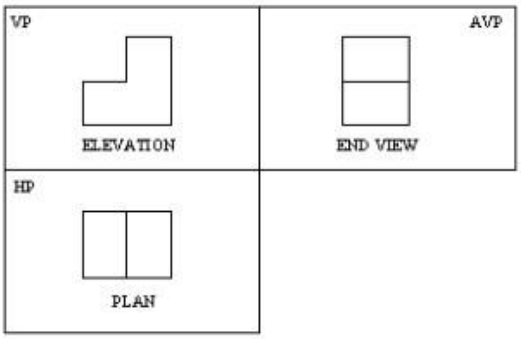
Figure 2.12 Orthographic projection of an object onto the auxiliary plane

When the planes of First Angle Projection are unfolded, there are three views as follows:

(i) ELEVATION (vertical plane)

(ii) PLAN (horizontal place)

(iii) END VIEW (auxiliary vertical plane)



(b) Third Angle Projection

The Third Angle Projection method assumes that the object is placed in the third quadrant (third angle) and then projected onto different planes.

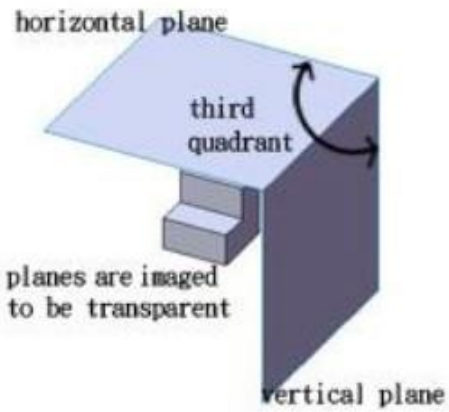


Figure 2.13 Object in the third quadrant

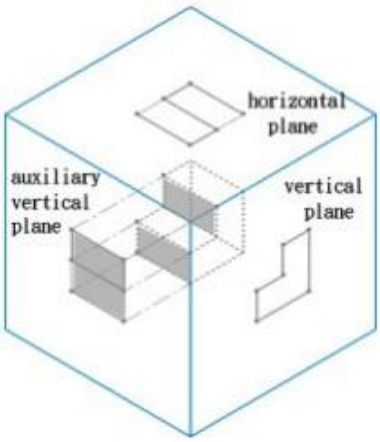


Figure 2.14 Projection of an object onto three separate planes

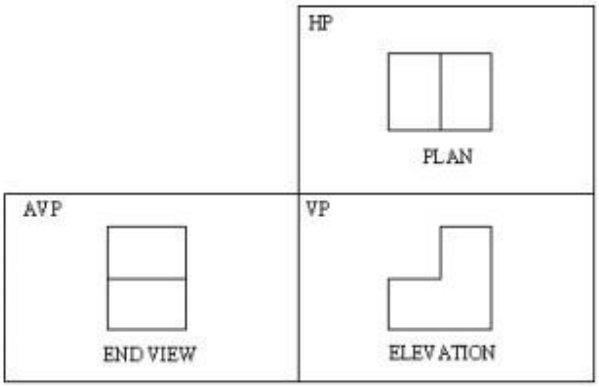
The principal planes are located between the viewer and the object. Thus, the viewer should imagine that the planes are transparent, in order to observe the views of the objection planes.

When the planes of Third Angle Projection are unfolded, there are three views as follows:

(i) ELEVATION (vertical plane)

(ii) PLAN (horizontal place)

(iii) END VIEW (auxiliary vertical plane)



2.2.3 Assembly and sectional drawings

(a) Assembly drawings

- An assembly drawing shows how components are fit together. It usually includes orthographic views and sections for showing the details and relative positions.
- A parts list tabulates all individual parts of an assembly. It usually contains the number, the name, the material and the quantity of each assembled part.
- Under the balloon reference system, each part number in the parts list is indicated with a “balloon” for reference.

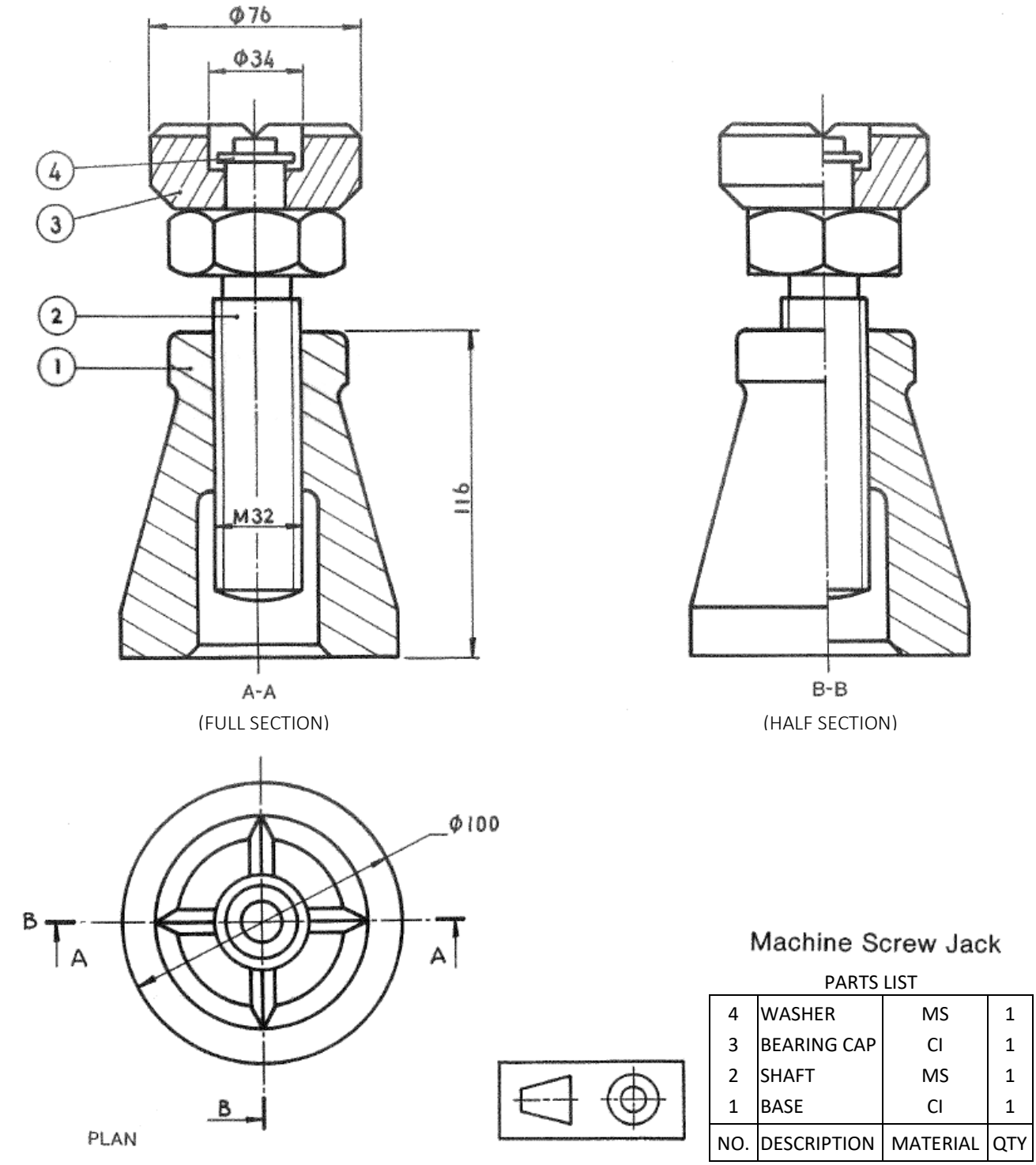


Figure 2.15 Location of parts shown with the balloon reference system in an assembly drawing

(Source of Figure 2.15, 2.16 & 2.19: Technical Drawing 5, VISION Publishing Company)

An assembly drawing is usually attached with details drawings corresponding to the numbers in the "balloons".

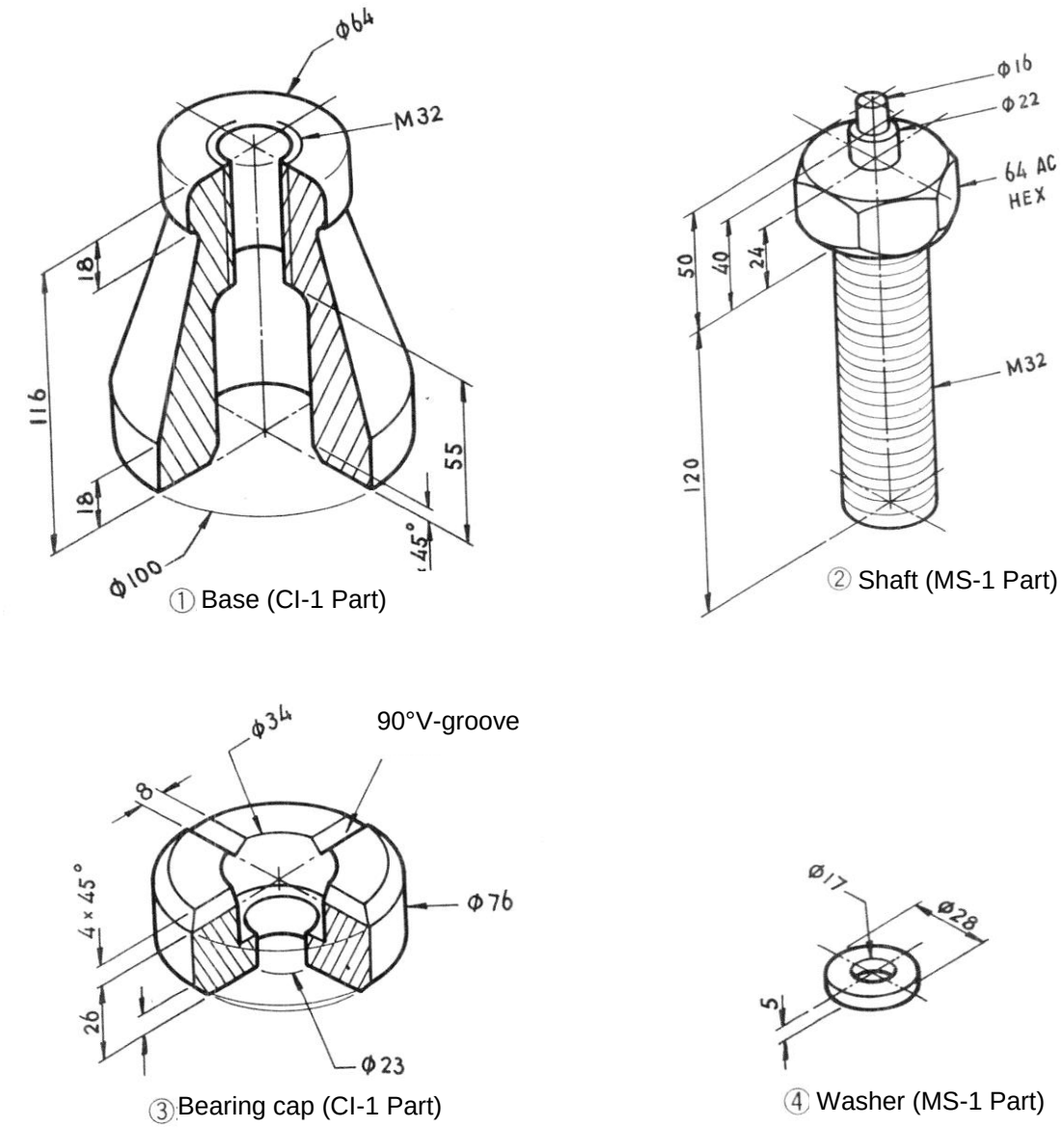


Figure 2.16 Details drawings (pictorial method)

(b) Sectional drawings

Sectional drawings are used to show the internal structure and relevant components of an object. When drafting a sectional drawing, pay attention to the followings:

1. The cutting plane is the internal plane of a cut-through object
2. The parts separated in the plane are called "sections"
3. A sectional view is a drawing of sections
4. The section line X-X shows the position of the sectional plane
5. A sectioned part of an object is shown by shading with thin lines (section lines) of 45° that touch the visible outline
6. Section lines of two adjacent parts should be in opposite directions

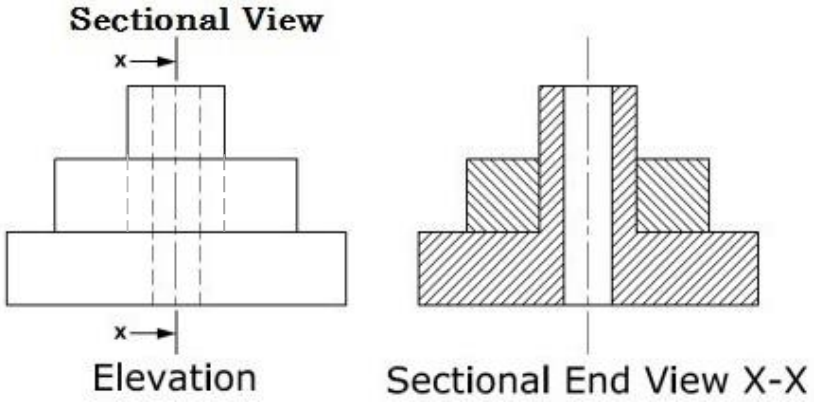


Figure 2.17 An orthographic projection showing both elevation and sectional end views

Different ways to cut through the object lead to different sectional results. There are four common types of sectional drawings as follows:

1. Full section 2. Half section 3. Part section 4. Offset section

There can be many different sectional drawings for a single object. The following figure shows how a sectional drawing is drafted based on different section lines.

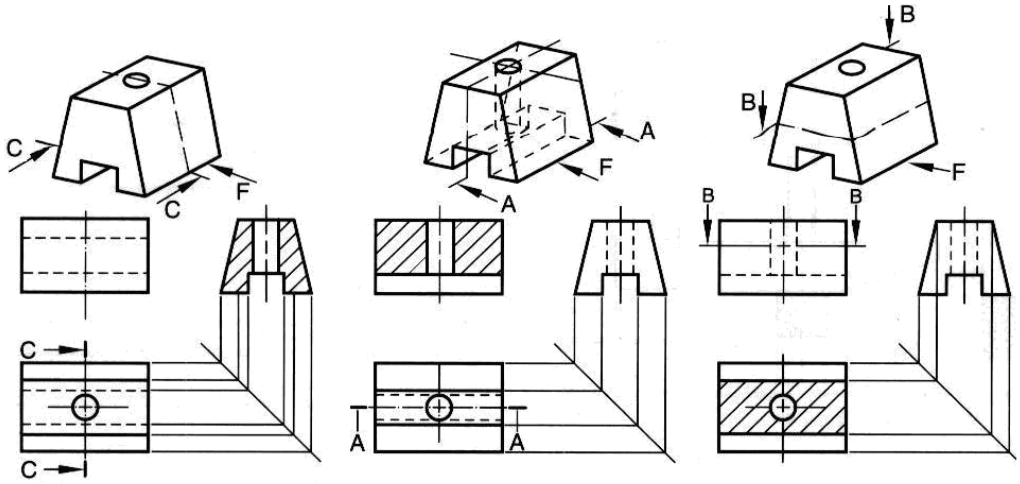


Figure 2.18 It is easier to draft sectional drawings with orthographic projections already completed

2.2.4 Parts drawing

- A parts drawing is a document describing in detail all the items required for mechanical equipment production and their characteristics.
- A parts drawing can be drafted with either the orthographic projection method or the pictorial method.
- The pictorial method, which results in only one drawing, may reduce the number of views but are rather time-consuming. It is more suitable for simple parts.

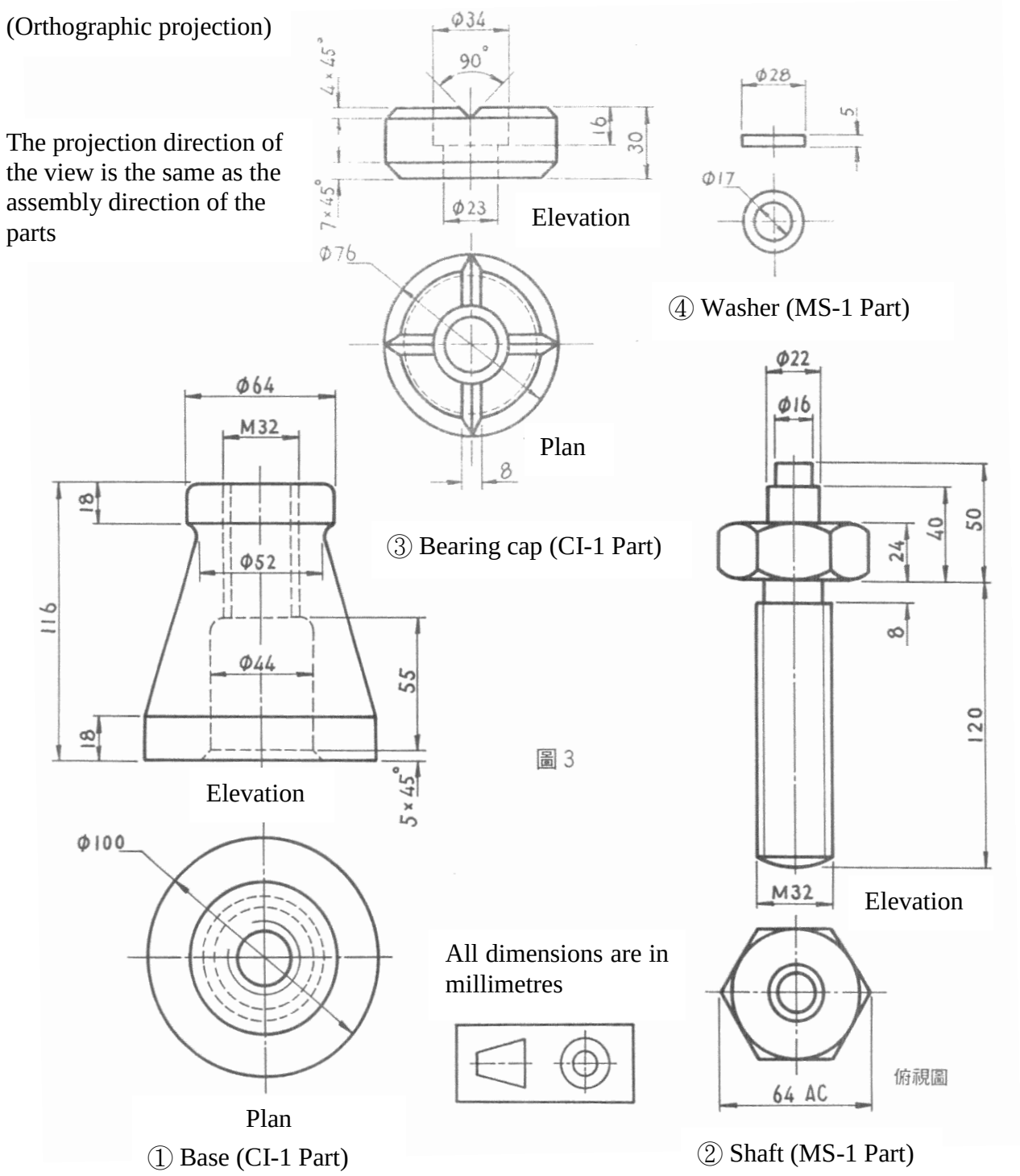


Figure 2.19 Parts drawing (orthographic projection)

2.3 Standards, Conventions and Symbols

- To avoid misunderstandings and mistakes, different stakeholders (such as architects or engineers) should adopt the same standards, conventions and symbols in engineering drawings, such as those used in floor plans.
- Symbols carry only certain characteristics of the appearance of objects that they represent. Most of them are single lined. The major purpose of using symbols is to facilitate designers' drawing and readers' recognition.

2.3.1 Architectural drawings

- Architectural drawings are generally derived from orthographic projections, but have a set of unique terms, standards and symbols.

(a) Floor plans

- Floor plans give a complete record of the walls, windows, doors and other information on the floor.
- It is a market practice to have the front door placed at the bottom of the plan.

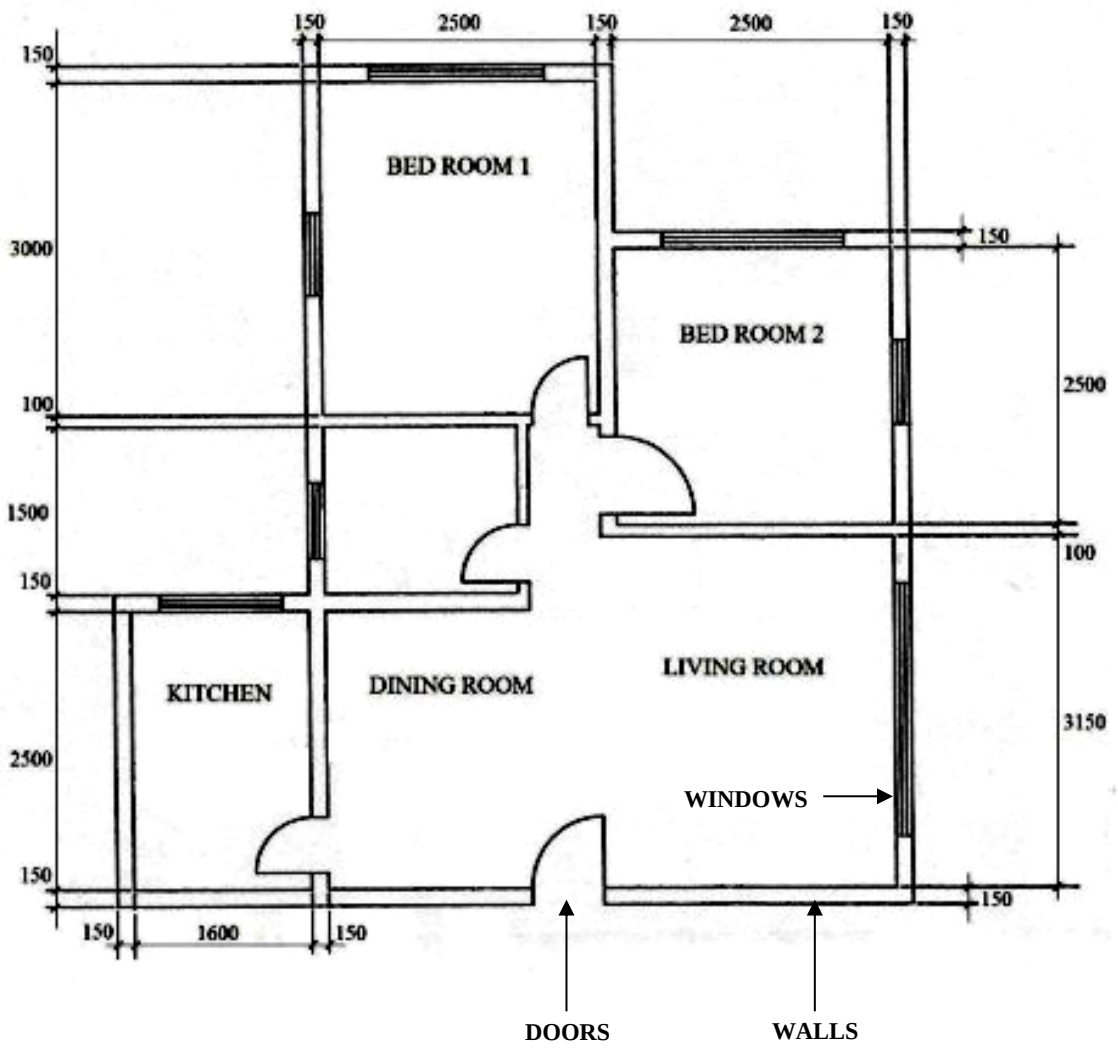


Figure 2.20 An example of floor plan

(b) Building works plans

- A building works plan is mainly intended to provide engineers with detailed information of the building concerned, for the sake of accurate construction.

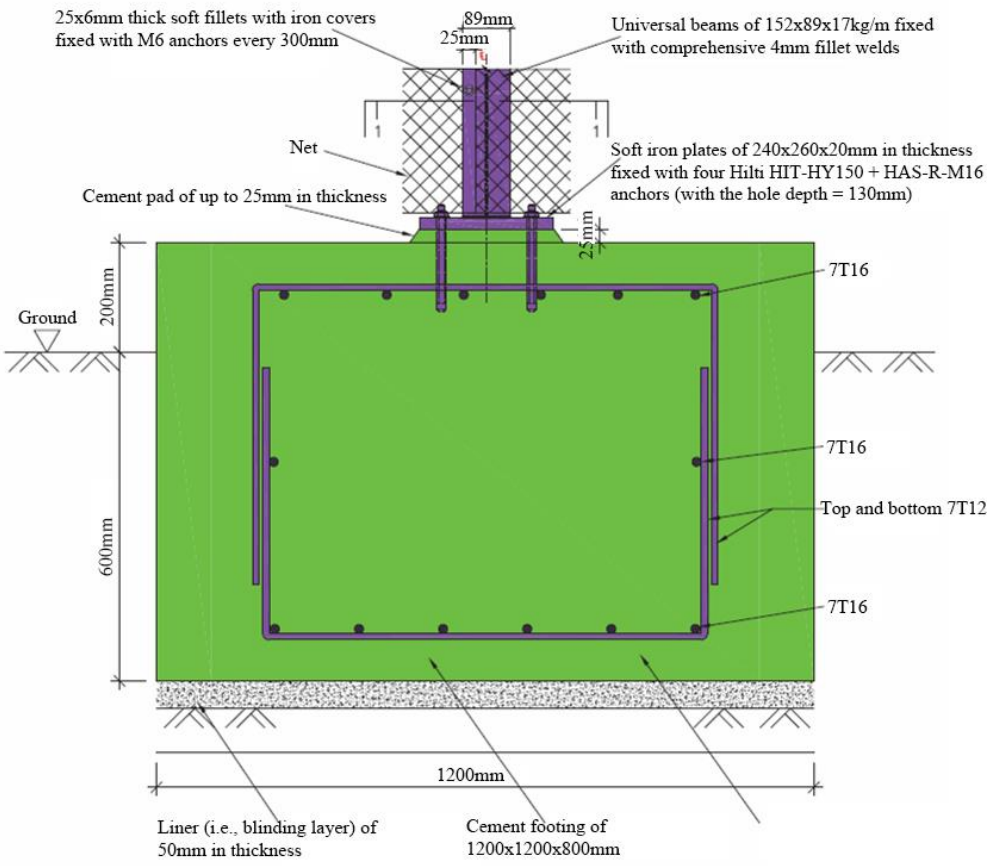


Figure 2.21 A building works plan (Source: Buildings Department)

(c) Building elevations

- The exterior appearance and functionality of a building should not be ignored. But its taste, function and cost should be balanced as well.
- Information about the appearance of a building may be shown in other views.

(d) Sectional drawings

- Similarly, sectional drawings are also used in architecture to show the interior views and architectural details of buildings.
- Sectional architectural drawings are used to show the locations of different furniture and areas, such as the cupboard, the kitchen and the bathroom.

Figure 2.22 Building elevation and section

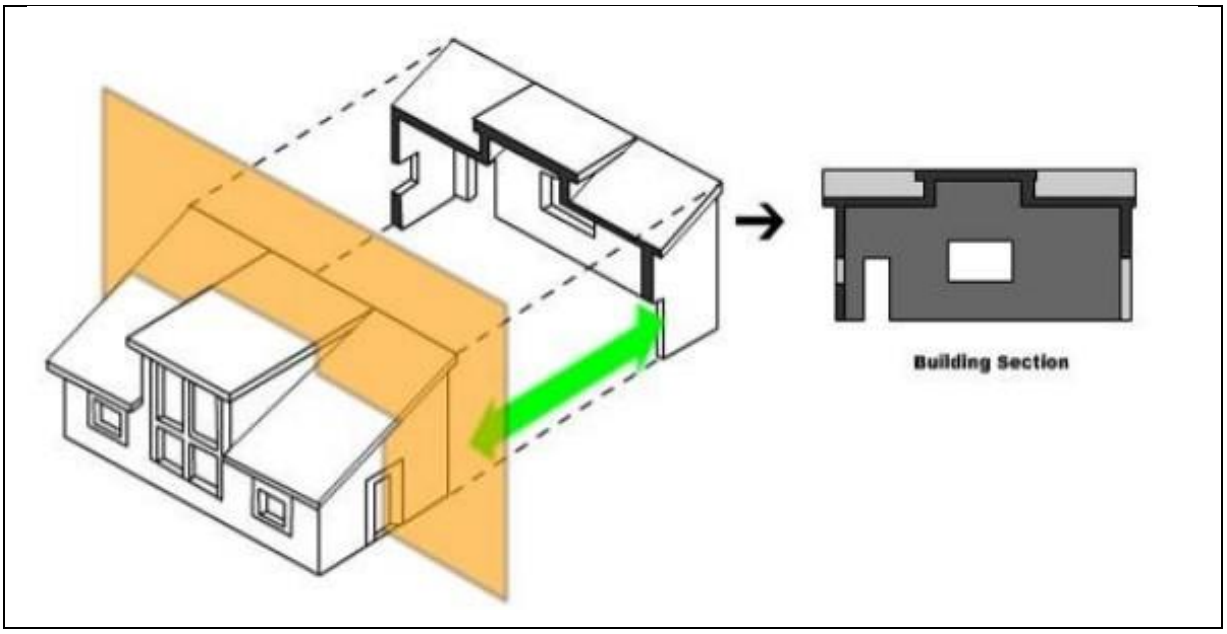


Figure 2.23 Building Sectional drawing

(e) Architectural drawing scales

- The common scale for a floor plan is 1:100. In other words, a length of 10 mm on the drawing represents 1000 mm (l m) on the actual building.
- For small buildings, a smaller scale, such as 1:50, can be used to show more details.
- The site plan of a small building is usually in a scale of 1:200, 1:500 or even 1:1000.

(f) Dimensioning of architectural drawings

- Dimensions of architectural drawing are usually in millimetres (mm). It facilitates scale conversion, such as from 37.5 m to 37,500 mm and vice versa.
- For the outside part of the object area, projection lines can be used to show dimensions of interior features.
- In many cases, in order to avoid overcrowding the interior of a drawing, projection lines do not originate from the actual feature.

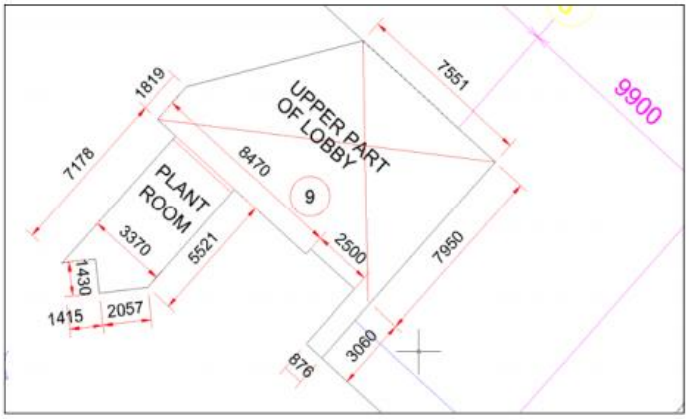


Figure 2.24 Example of dimensioning of architectural drawing

(Source: Buildings Department)

2.3.2 Architectural electrical drawings and electronic circuits diagrams

- There are usually electric drawings for construction projects to indicate the types, locations and other details of electrical facilities.
- Electrical drawings sometimes added with other equipment (such as gas connection points) and become electrical & mechanical provisions plans.

(a) Electrical architectural symbols

- The symbols used by different international organisations vary.
  - i. Standards Australia
  - ii. British Standards
  - iii. National Standards (*Guo Biao*, GB)

Engineers must check for any updates before producing electrical drawings.

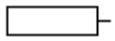
(b) Electrical architectural symbols and floor plans

- Both specifications for electrical wiring and floor plan drawings are instructions for electrical installation. The specifications include:
  - (i) Wiring methods and materials
  - (ii) General layout methods
  - (iii) Types of accessories to be used
  - (iv) Mounting heights of switches and outlets

(c) Size of electrical architectural symbols

- It may not be suitable to draw electrical facilities proportionally (e.g. 1: 100) on a floor plan, since socket outlets may become minuscule.
- The size of the symbols has no meaning with the actual size of an outlet or appliance.
- The size of symbols ranges from 3.5 mm to 5 mm in general. Otherwise, the symbols are either too small for readers to read, or too large to fit into a drawing.

Below are some common symbols of electrical facilities:

Category	Descriptions	Symbol
Lighting equipment	Signal light	
	Self-contained emergency luminaire	
	Fluorescent luminaire (commonly known as fluorescent tube): general symbol	
Distribution box	General symbol	
Electrical appliance	General symbol (use a designation to specify the type if necessary)	
	Air Conditioning	AC
Switches	Single-pole one-way switch	
	Single-pole two-way switch	
Socket outlet	General symbol	
Others	Electric bell	
	Exhaust fan	

Reference: Code of Practice for the Electricity (Wiring) Regulations (Annex 8), Electrical and Mechanical Services Department of Hong Kong (2015 Edition)

Electronic Circuits are commonly used to indicate the types of electronic components and their connections, the figure on the right shows a simple circuit which contains three parts:

1. A source of electric charges or electrical potential difference (such as a battery).
2. A conductive path that allows movement of charges (such as a copper wire).
3. An electrical or electronic component with a specific function (such as a light bulb).

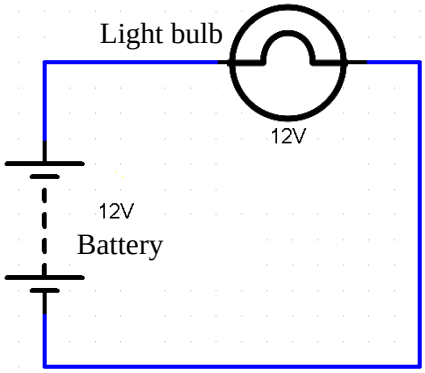
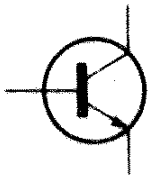
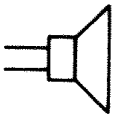
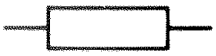
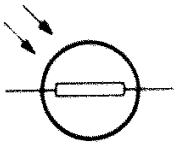
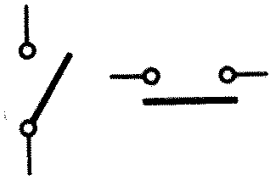
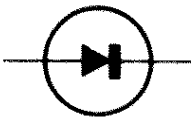
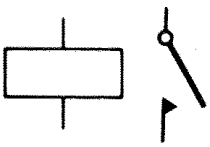
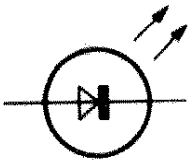
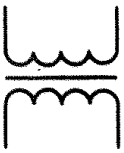


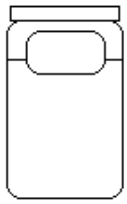
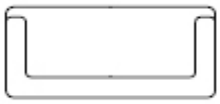
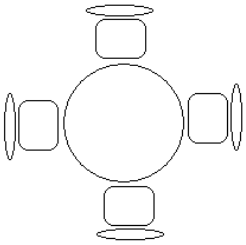
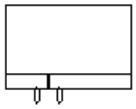
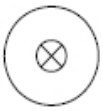
Figure 2.25 A simple circuit

Below are some common symbols of electronic components:

Battery		**npn transistor**	
Light bulb		**Speaker**	
Resistor		**Generator**	
Light dependent resistor		**Motor**	
Capacitor		**Switch (NO)**	
Diode		**Relay**	
Light Emitting Diode (LED)		**Transformer**	

2.3.3 Furniture and appliance symbols

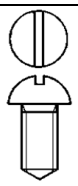
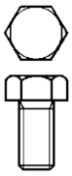
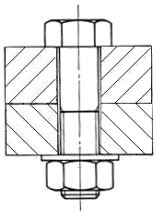
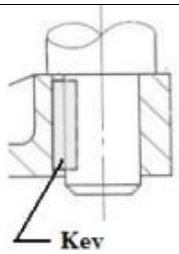
At present, there are no specific symbol standards for the layouts of furniture and household appliances in architectural drawings. Some examples of comprehensible symbols are listed below:

Bed	
Sofa	
Chair	
Desk	
Dining table with chairs	
Refrigerator	
Computer monitor	
Computer keyboard and mouse	
Lamp	

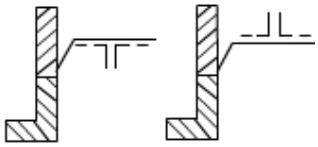
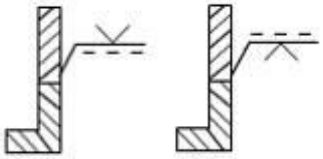
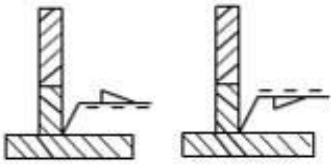
2.3.4 Fastening devices symbols

- Temporary fastenings are items that can be withdrawn or replaced at any time, such as screws, bolts, nuts and keys.
- Permanent fastenings are items that involve destruction of the jointing elements if separated, such as riveting and welding.

(a) **Examples of temporary fastenings**

Screws	Slotted Countersunk head	Slotted Round head	Phillips Countersunk head	Hexagonal head
				
Bolts and nuts				
Keys				

(b) **Examples of permanent fastenings**

Rivets	
Square butt welds	
Single-V butt welds	
Fillet welds	

2.4 Data Presentation

The following information must be presented to the audience clearly and objectively:

(a) Features of the design

(b) Data gathered and analysed

(c) Benefits of implementing the design

2.4.1 Types of presentations

(a) Informal presentations: The audience are a group of industry insiders knowledgeable about the design.

(b) Formal presentations: The audience are a larger group of people with different interests.

2.4.2 Visual aids

Visual aids, such as charts, graphs and models, are more effective than simple lecture notes in presentations. Here are some suggestions:

(i) Each visual aid should be limited to a single concept;

(ii) Illustrations, colours, etc. can draw the audience's attention more easily;

(iii) Only key points should be shown on presentation slides; and

(iv) Texts should be in large font size for easy reading.

(a) Charts

There may be a large amount of data to present in the design process. Charts of appropriate types can be used for the purpose.

(1) Bar Charts: They can display and compare the values of different components.

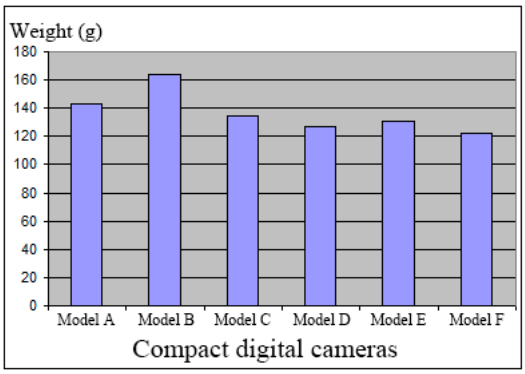


Figure 2.26 Bar chart

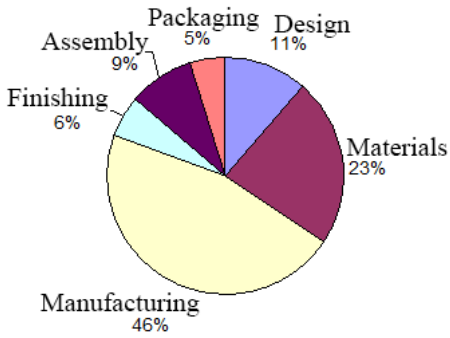


Figure 2.27 Pie chart

(2) Pie charts: They can show the proportions of components out of 100% within a set.

(3) Line charts: They can show the quantity change of an individual item, and are therefore suitable for illustrating the relationship between a single item and the time.

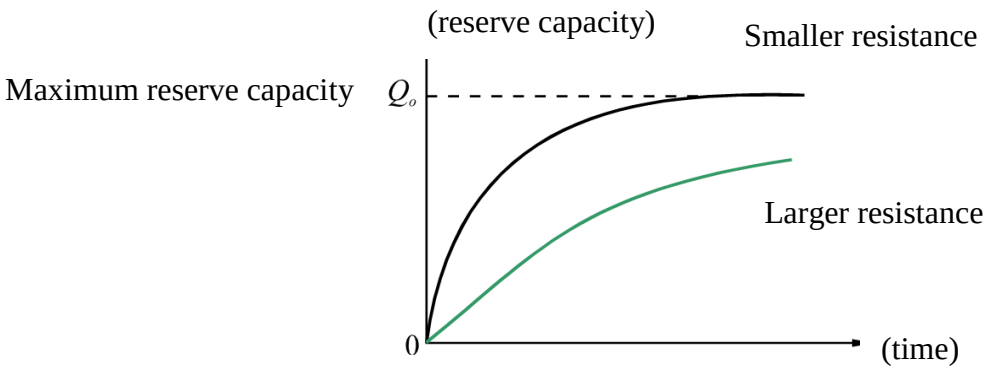


Figure 2.28 Line chart

(b) Sequential drawings

They can be used to demonstrate the dynamic effects of a design, such as how different parts can be assembled.

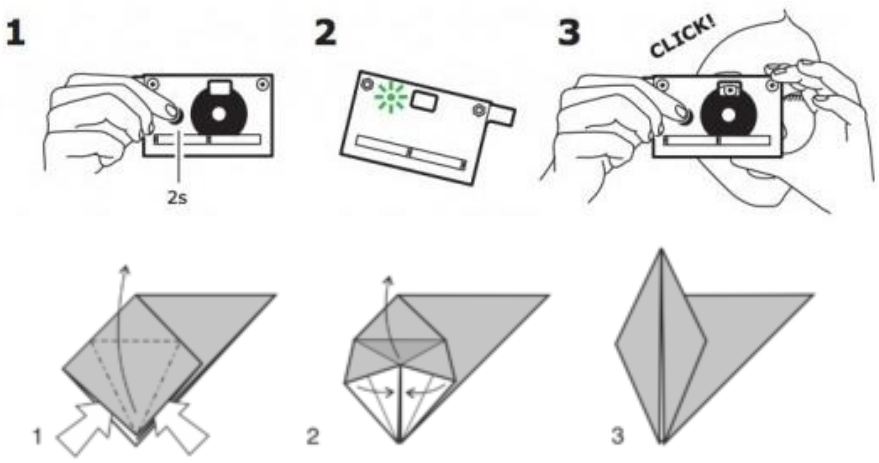


Figure 2.29 Examples of sequential drawings

(c) Trademarks, symbols and logos

In the design of trademarks, symbols, road signs, sign posts or logos, the following factors should be considered:

(i) Meaning
(ii) Creativity
(iii) Feasibility
(iv) Colouring
(v) Presentation skills

Figure 2.30 Traffic sign (No parking)

Figure 2.31 Logo (Wikipedia)

(d) Models

- Models are the most convincing visual aids, and should be large enough to be seen by the audience.
- To enhance the presentation effects, close-up photographs from different angles of the model may be provided.

Figure 2.32 Model

(e) Multimedia presentation

Slides can be shown on the computer (for a small group of audience), or projected onto a big screen (for a large group of audience).

(i) Texts may be presented in different colours, styles and font sizes.

(ii) Presentation slides may include multimedia effects, such as photos, videos, special effects and animations.

2.4.3 Presentation scripts

- The presenter usually prepares a script listing key points of the presentation.

2.4.4 Presentation podium

- The presenter should make good use of the presentation podium by referring the slides while facing the audience, and also using a pointer to emphasize some points on the screen.

2.4.5 Presentation skills

- **Layout:** A good presentation should have an attractive introduction, a logical body and a clear conclusion to facilitate the audience's understanding.
- **Arrangement of visual aids:** Tables, diagrams and multimedia visual aids must be arranged properly to highlight key points.
- **Use of non-verbal communication:** The presenter should make good use of non-verbal communication means, such as gestures and eye contact, so as to convey messages in a more effective manner.

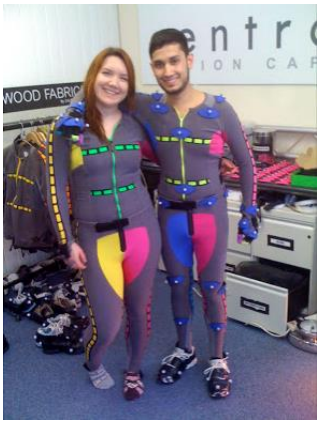
2.4.6 Standards

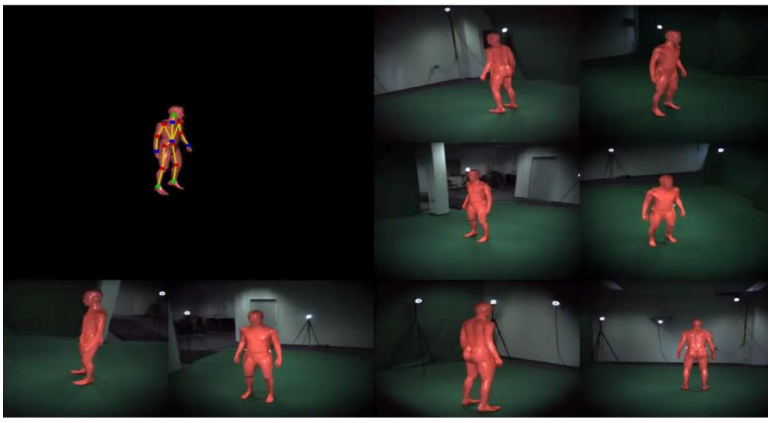
- In the design process, standards or conventions should be followed whenever possible, so as to deliver information clearly and accurately.
- Standards generally specify the relevant design requirements, such as presentation methods, units, abbreviations and symbols.
- Different categories of product designs are subjected to specific standards or conventions, such as British Standards (BS) and ISO standards.

Example: Engineering drawing BS8888

Know More About Technology- Motion capture

Motion capture is the technolgy of recording the movement of objects or people. It is used in military, entertainment, sports, medical applications, and for validation of computer vision and robotics etc.





Chapter 3 Computer-aided Design (CAD)

3.1 Prototypes

- A prototype is the model used for testing the functions of a product before mass production.
- There are generally three types of prototypes, namely handmade, virtual and rapid prototypes, each with different characteristics.

3.1.1 Handmade prototypes

Traditionally, handmade prototypes were manufactured manually and the process was time-consuming. There are different handmade prototyping applications, such as solid models of mechanical objects.

Figure 3.01 A series of physical prototypes and the final product

Figure 3.02 Physical prototype of the car (1980s)

3.1.2 Virtual prototypes

- A CAD system can be used to draft design drawings, so that a 3D model is rapidly generated as the virtual prototypes.
- A virtual prototype is a computer simulation system or subsystem that is functionally similar to the physical one.
- In the early stages of the design process, a virtual prototype can be used to review and evaluate design features before a physical prototype is made.
- Since the 1980s, CAD has been used to design and produce virtual prototypes.
- Like physical prototypes, virtual prototypes can undergo complicated testing and analysis, in terms of material features, stress, etc.

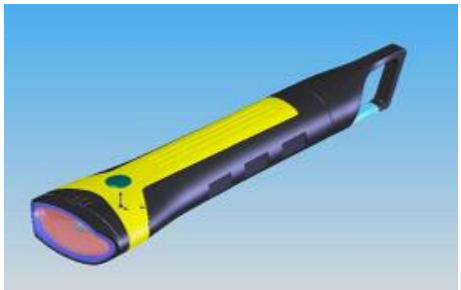


Figure 3.03 Virtual prototyping

Figure 3.04 Rapid prototyping

3.1.3 Benefits of virtual prototypes

- Good impression to buyers
  - Enabling interactions with buyers
  - Demonstrating the uses, functions and values of the product through animation
- Broader sales channels - Wide distribution to potential buyers through electronic means at a lower cost
- Low-cost development - Easy and low-cost modification.
- Sophisticated design - Easy and low-cost modification, resulting in the most sophisticated products

3.1.4 Rapid prototyping (RP)

RP enables rapid creation of physical prototypes to reduce the time of product testing and improvement.

- Short lead time and cost effective for hard prototyping
- Possible for limited testing
- Possible for sales and marketing
- Clearer presentation

RP uses 3D model data to produce a physical model rapidly.

RP techniques include "stereolithography", "layered manufacturing", "3D printing" and others.

A physical prototype not only enables a clear view of the product design, but it can also be used for testing. For example, RP can produce

- Airfoil-shape models for wind tunnel testing
- Plugin models for tooling, such as silicone rubber moulds
- Models and parts in complicated shapes

3.1.5 Product development process

There are five components in a typical product development process, namely:

(a) Design: The designer designs a new product with CAD software

(b) Analysis: If the design is accepted by the client, it is then further analysed and optimised, and manufacturing specifications are drafted

(c) Manufacturing: Upon the completion of design analysis, the stage of pilot run commences

(d) Inspection: End products are inspected to ensure their compliance with the client's requirements

(e) Production/assembly: Information finalised along the product development process is used for mass production

Some stages may overlap in the product development process. For instance, design and manufacturing may be carried out at the same time.

3.1.6 The role of virtual prototyping (VP) in product development process

- The specifications of product design consist of both geometrical and non-geometrical data. Non-geometrical data refer to materials, hardness, etc.
- VP can show non-geometric data (such as materials) which cannot be displayed in engineering drawings, for the designer's reference.
- Basic activities of a product development process are shown as follows: Products can be launched in the market after they are assembled.

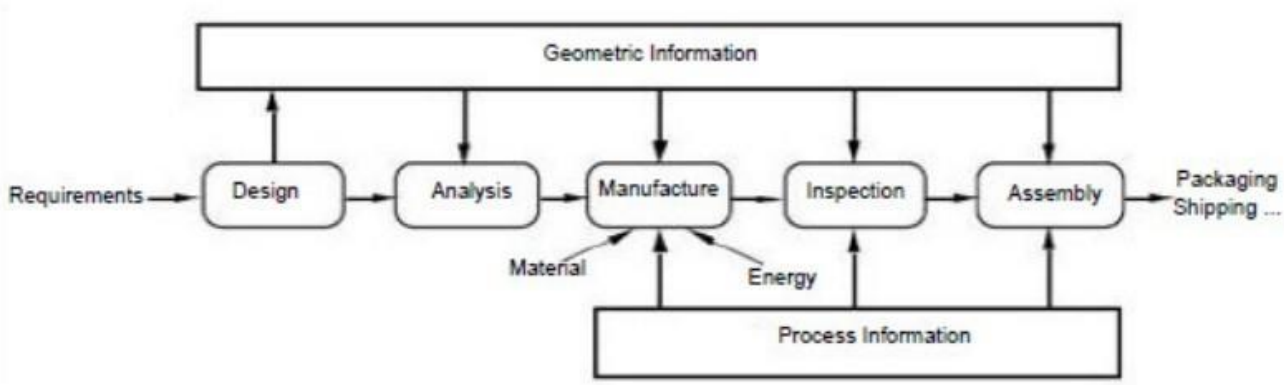
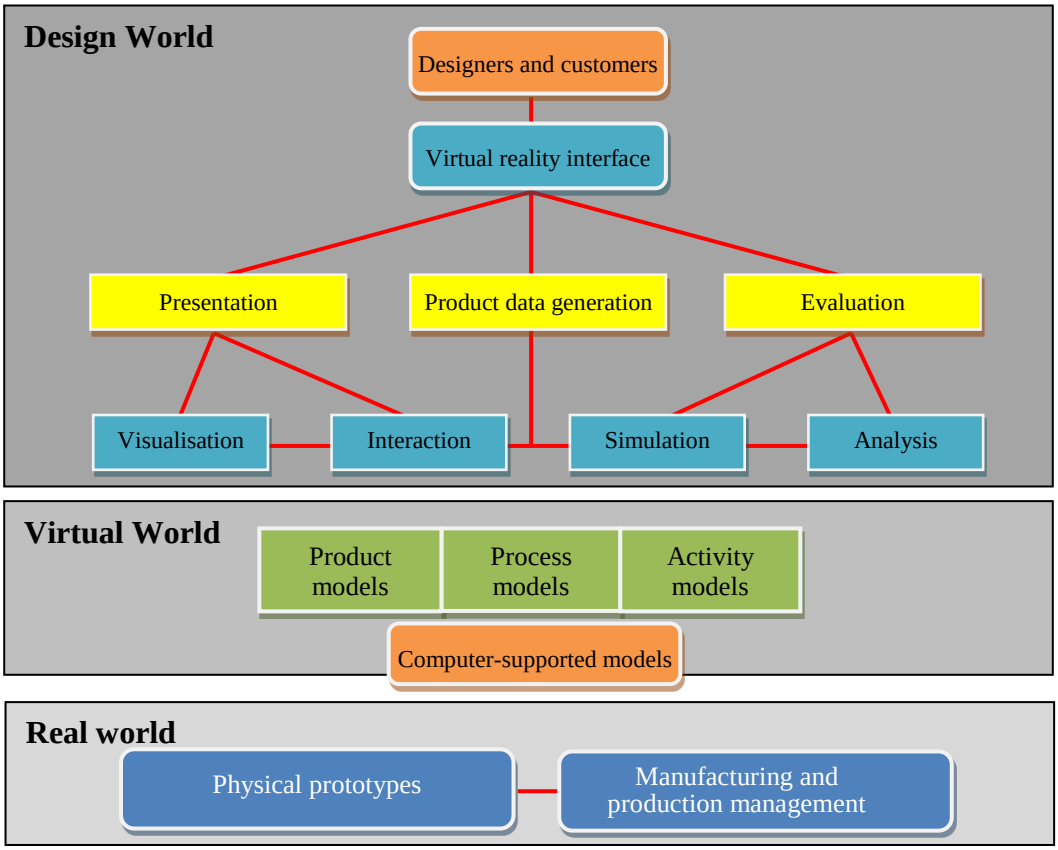


Figure 3.05 Product development process

Virtual prototyping allows designers to:

- Create realistic 3D computer models as replicas for operation and analysis
- Integrate elements such as modelling, simulation, target products and production in the virtual world, and interact with the design world
- Form a virtual design by combining product definition, design engineering and manufacturing

The principle of a VP-aided design



3.1.7 Comparison between virtual and physical prototypes

Virtual and physical prototypes have their respective advantages, disadvantages and requirements, as illustrated in the following table:

Aspect	Virtual prototype	Physical prototype
Equipment requirements	High-performance computers and display equipment	Hand tools and light machinery
Technical requirements	Design software technology	Material processing technology
Production costs	Low material costs High set-up costs Low modification costs	High material costs High set-up costs High modification costs
Presentation effects	More variations Easy presentation with animation and multimedia	Mainly static presentation Presentation with actual operation
Distribution	Easy distribution (available electronically)	High shipping costs with difficulty
Storage	Easy mass storage in electronic devices	A lot of space required for storage and maintenance

When selecting a prototyping method, we should firstly consider whether existing conditions meet the requirements before considering the pros and cons.

3.1.8 VP techniques

(a) Modelling

- Modelling refers to shaping models of a design product.
- Modelling is usually used for assessing the performance of a product in various scenarios. Virtual prototypes can reduce errors.
- It illustrates the future performance of a product within a short time
- It can swiftly detect any changes affecting the product quality

(b) Simulation

- Simulation refers to the reproduction of workflows or processes in order to observe the expected results.
- Simulation is conducive to testing the production process and the results are useful for designing products in the most effective way.
- Modelling and simulation provide useful data for improving operations and may be used to test other alternatives.
- Simulation can improve the product development process and identify the root causes of problems
- It can test production controls and product flows before actual commissioning
- It is helpful in planning production lines and activities
- It explores alternatives and variables for the best solution

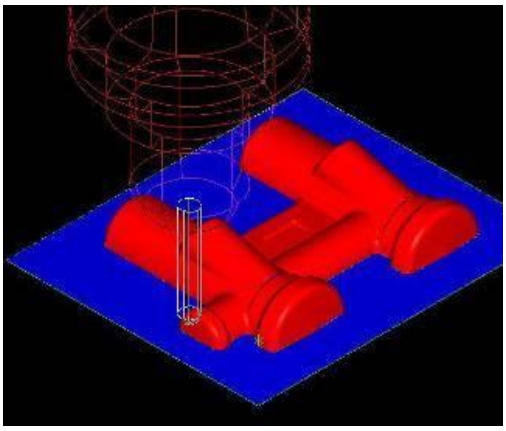


Figure 3.06 Simulating the manufacturing and operation process on a computer

(c) Kinematic analysis

- "Kinematic analysis" refers to the use of virtual prototypes to consider the exertion of forces and the mechanical performance.
- Design software applications enable the creation of mechanical devices, 3D models with complex structures and animated images.

Kinematic analysis has the following benefits:

1. Visualising design performance, and calculating velocities, accelerations and loads
2. Revealing potential problems, such as vibrations and dangerous deflections
3. Rotating 3D models to test the appropriateness of parts
4. Detecting parts with repetitive motions, such as gears and linkages
5. Simulating events which happen instantly in reality, such as car accidents
6. Simulating tests before they are actually conducted, such as artificial limbs or organs, deep-sea oil-drilling and satellites

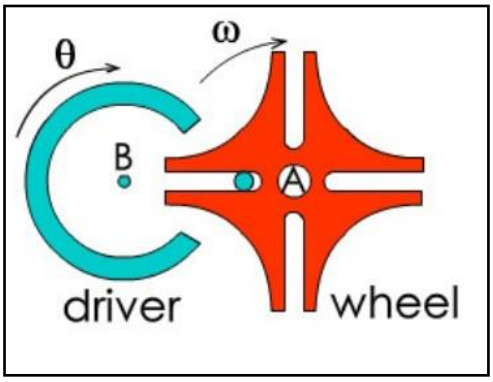


Figure 3.07 Kinematics analysis diagram

(d) Product realisation and modification

Virtual modelling has two major benefits, namely

(i) Creating substitutes for real objects

(ii) Identifying feasible solutions for problems

Traditional hand drawings and hand-crafting consume a lot of time and resources.

Using CAD/CAM software enables the swift production of sophisticated 3D models which can be modified easily.

Major development patterns of virtual modelling are summarised as follows:

- **Parametric modelling**

  The user specifies parameters to control the properties, such as shape and size, of a 3D parametric model.

- **Constraint-based modelling**

  The user creates a model by specifying constraints on design elements, such as "Holes A and B are of the same diameter".

- **Feature-based modelling**

  The user creates 3D models by specifying features, such as bosses, chamfers, fillets, holes and pockets.

3.2 Criteria for Computer Modelling Techniques

3.2.1 Fundamentals of graphic systems

There are two categories of computer graphic images, namely vector and raster.

1. A raster image is a collection of dots, and is usually called a "bitmap image".

"Raster images editor" such as "Adobe Photoshop" and "Corel Painter" can be used to create and edit raster images.

2. Vector graphics include lines, squares, rectangles, circles, etc. which are represented as mathematical formulae.

"Vector graphics editor" such as "AutoCAD", "CorelDraw" and "Adobe Illustrator" can be used to create and edit vector graphics.

The following picture shows the effects of magnified vector and raster graphics. The label on the left is a vector image.

- When it is magnified by a vector graphic editor, the enlarged image is a vector one as shown in the upper-right circle.
- When it is magnified by a raster image editor, the enlarged image is a bitmap as shown in the lower-right circle.

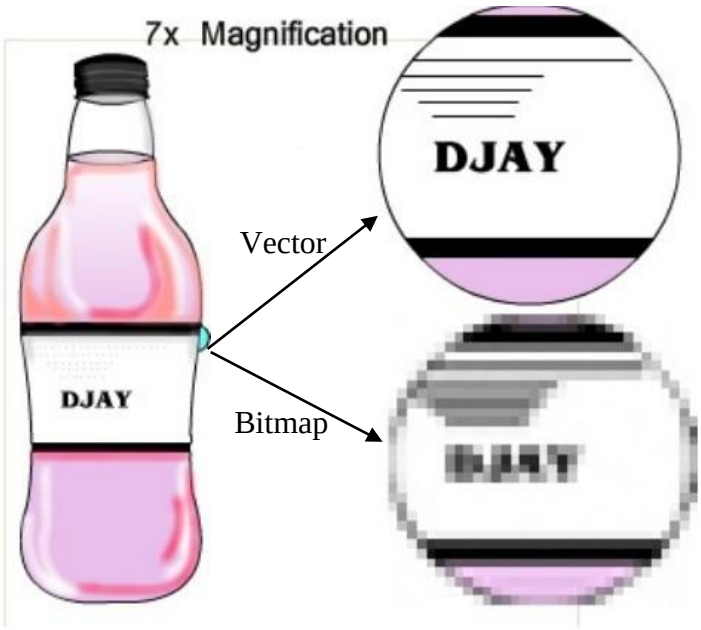


Figure 3.08 The effects of magnified vector and raster images

Computer monitors, printers, optical scanners and fax machines are some of the common raster devices.

- Monitors display images as a matrix of dots, or "pixels". The image has to be firstly "rasterised", or converted into a dot pattern.
- Also, a vector graphic has to be rasterised into a pattern of ink dots before it can be printed.
- Texts and pictures are also rasterised into bitmap images by optical scanners or fax machines before they can be processed.

(a) Raster images

- A raster images consists of many dots (pixels), like a piece of "mosaic" artwork made of small blocks.
- Raster images are usually measured in dots per inch (dpi).
- A greater dpi value means a higher resolution and subsequently a better image. For example, an image on the web can be 72 dpi, while a high-resolution image should be 300 dpi or more.

This bitmap image shows jaggies when magnified ten times.

Figure 3.09 A bitmap image

Resolutions of raster images

- The resolution of a printer or a scanner is also measured in dpi, while the output quality depends on the resolution of the original image.
- Therefore, the printing quality of a 300 dpi raster image on a 300 dpi laser printer is identical to that on a 600 dpi one.
- Enlarging a raster image is enlarging each pixel, so the jaggies become more obvious.
- The printing quality of a raster image is determined by the original resolution of the image, the performance of the printing device, the magnification and some other factors.
- Some devices, such as laser cutting machines, rapid prototyping and CNC machines, manufacture physical products based on images. So the resolution affects product quality.

File formats of raster images

When optically scanned, images or words become raster images.

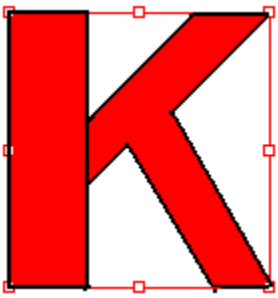
Some common file formats of raster images are listed below:

(i) BMP (Windows Bitmap)
(ii) GIF (Graphics Interchange Format)
(iii) JPEG (Joint Photographic Experts Group)
(iv) PNG (Portable Network Graphics)
(v) PSD (Adobe Photoshop)
(vi) TIFF (Tagged Image File Format)

(b) Vector graphics

- Vector graphics are represented by geometric primitives based on mathematical equations (points, lines, curves or polygons, etc.).
- The vector graphic of a circle, for example, only stores information such as the position of the centre, the radius, the line weight and the colour. The file is generally small.
- Vector graphics are used mainly to draw objects, so they are object-oriented. On the contrary, raster images are pixel-oriented.
- Generally speaking, animations are made in vector graphics, but they should be rasterised before they can be displayed on the screen or be used for bitmap printing.

A vector image



This vector graphic is surrounded by eight anchor points in the red square. The object can be scaled up or down by dragging any anchor point with the mouse.

Figure 3.10 A vector graphic

Resolution of vector graphics

- The resolution of a printer or a scanner imposes no limits on vector graphics.
- When a vector graphic is scaled up or down, the computer draws the image again by recalculating the mathematical equation. The quality of the image is not compromised as a result.

File formats of vector graphics

Some common file formats of vector graphics are listed below:

(i) AI (Adobe Illustrator)
(ii) CDR (CorelDraw)
(iii) DWG (AutoCAD)
(iv) EPS (Encapsulated PostScript)
(v) SVG (Scalable Vector Graphics)
(vi) WMF (Windows Metafile)

3.2.2 File format converting

- Vector graphics are represented mathematically while raster images are represented by pixels. The two are quite different.
- Some computer software (such as PostScript) can convert vector graphics into raster images ideally.
- Computer software applications converting raster images into vector ones are not yet perfect and need improvements.
- Some vector graphics can also store data containing raster images, which can be embedded into vector ones.
- On the contrary, raster images cannot store the data of vector graphics, which must be converted into raster ones before embedding.

3.2.3 3D CAD modelling

3D CAD modelling is the use of computers to process and display 3D model images.

3D modelling has the following advantages:

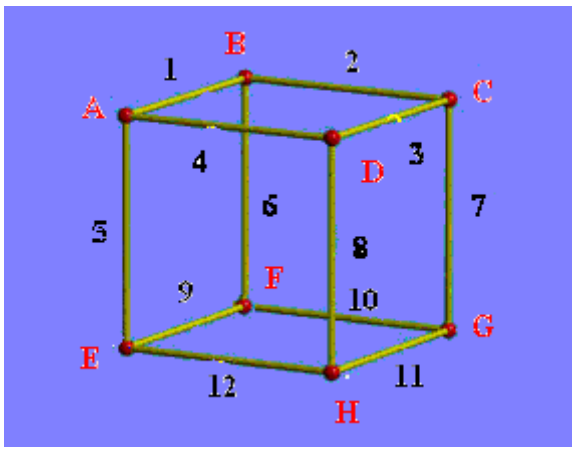
1. It is easier to handle a large number of complex drawings (such as those of pipe-work installations), thus improving the efficiency of design and manufacture.
2. It can automatically analyse physical properties (such as weight), and solve problems such as the inter-coordination and inter-penetration of objects.
3. Simulation of tool and robotic operations becomes possible.
4. It processes all primary data and information during product development to facilitate the design.

There are three different categories of 3D modelling in CAD, namely:

- Wireframe modelling
- Surface modelling
- Solid modelling

(a) Wireframe modelling

- A wireframe model consists of a vertex table and an edge table. It is considered the most primitive 3D object model.
- The vertex table keeps each vertex point with corresponding coordinates, while the edge table keeps the two incident vertices of every edge.
- The cube below has 8 vertices (red letters) and 12 edges (black numbers).



Advantages of wireframe modelling

- It is easy to operate and for users to construct with minimal training
- It takes less time and system memory to construct a model compared to surface or solid modelling
- A line model can easily change to a surface model

Disadvantages of wireframe modelling

- It may confuse users due to its ambiguous orientation and projection planes
- The drawing performance may decrease as the object complexity increases
- It requires both topological and geometric data, whilst solid modelling requires geometric data only
- It cannot be used for calculating volume and mass properties of objects

(b) Surface modelling

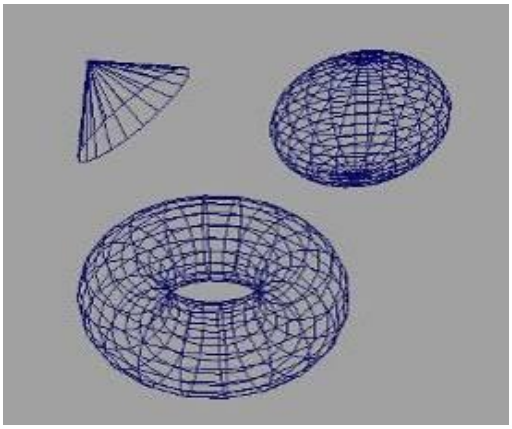
Surface models are based on points, lines and surfaces. Therefore, they are considered superior to and more flexible than wireframe models

Surface modelling is superior to wireframe modelling as follows:

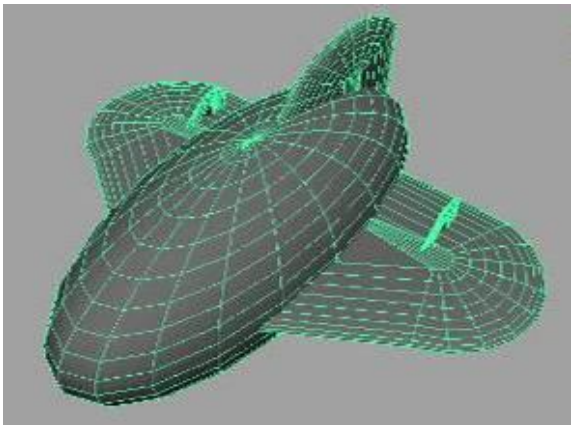
- It can recognise and display complicated curved profiles
- It can create 3D shaded surfaces with its face recognition ability
- It can recognise facial features, such as holes
- It can display superior 3D tool-path simulations for multi-axial machining operations and complicated shapes

Surface models are more suitable for designing and displaying complicated curved surfaces such as automotive bodies.

Examples of surface modelling



Surface analysis



Free form, curved surface or sculptured surface

Figure 3.11 Examples of surface modelling

(c) Solid modelling

Solid modelling is based on the sizes, volumes and shapes of objects, with comprehensive and clear descriptions.

Solid modelling features the following advantages:

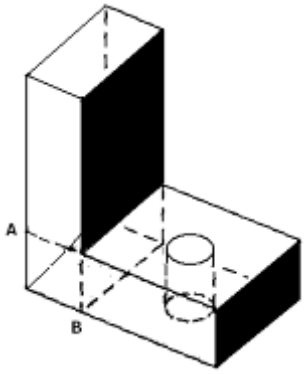
- It can differentiate the exterior and interior of an object, giving a full illustration of the volume and the shape
- It enables interior views of an object, facilitating the detection of unnecessary interference among components
- It carries no hidden lines
- It presents clear views of 3D sections even for complicated assemblies
- It facilitates the analysis and display of mass properties, as well as the construction of finite elements
- It can manipulate light & shadow and colouring effects, thus greatly enhancing the visualisation of shapes, components and cross-sections
- It can simulate mechanical movements, tool paths and the movements of robotic arms

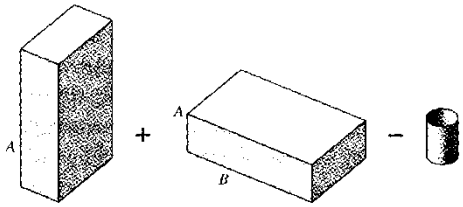
3.2.4 Primitives and features approaches

Primitives and features approaches are two ways of solid modelling.

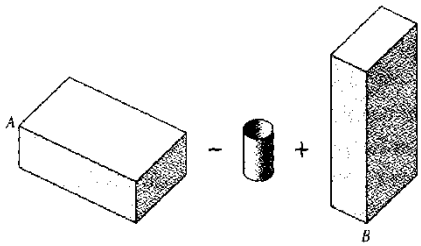
- Under the primitives approach, predefined shapes, also known as primitives, are used to create complicated solid models.
- Primitives can be boxes, cones, cylinders, spheres, wedges, tori (donuts), etc.
- Primitives are integrated to build a solid model.

Original object



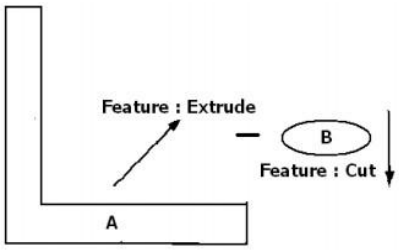


(a) Possible solid model of the object

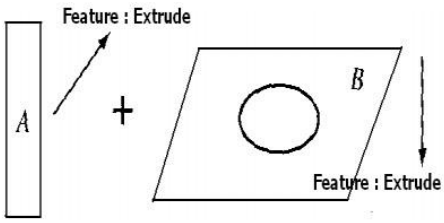


(b) Alternative solid model of the object

- Under the features approach, a solid model is built by means of different features (such as extrusion and cutting). It is more flexible than the primitives approach.



Possible sketch of the solid
(Extruding Profile A and cutting Profile B)



Alternative sketch of the solid
(Extruding Profiles A and B)

3.2.5 Constructive solid geometry (CSG)

- CSG is a common approach to create, modify and examine 3D computer solid models.
- A standard CSG primitive set consists of blocks, cubes, triangular prisms, spheres, cylinders, cones and torus.
- These basic primitives are operated with Boolean operators to build CSG solid models.
- If we use a tree as a metaphor, CSG is like the trunk, primitives are leaves, while Boolean operators are nodes.

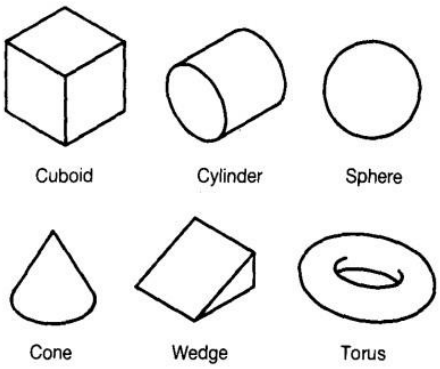
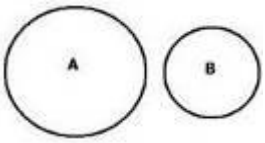
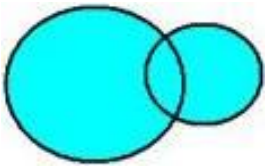
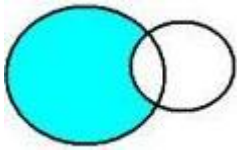
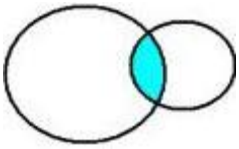


Figure 3.12 Geometric primitives offered by a solid modelling system

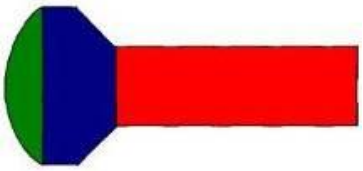
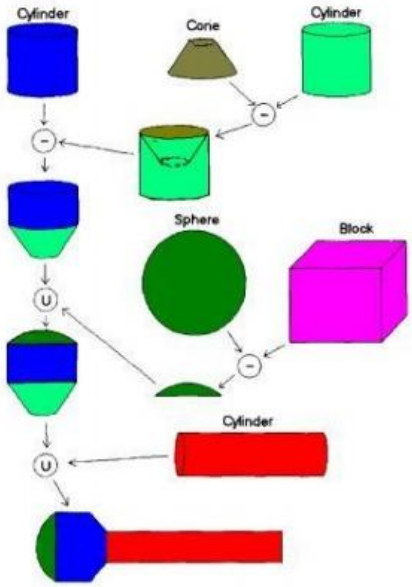
Boolean operations

In a Boolean operation, the set theory is used to define the relationships among primitives, namely union, difference and intersection.
The following table shows an outline and example of solid modelling of each Boolean operator.

SET THEORY	UNION (U)	DIFFERENCE (–)	INTERSECTION (∩)
			

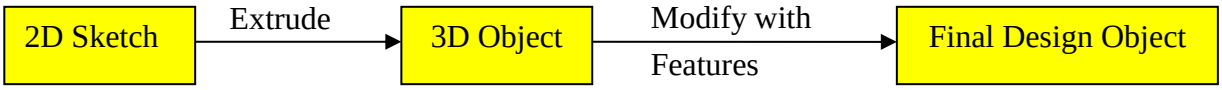
- A UNION (U) is the area of Bodies A and B combined. In other words, the shaded area of "A U B" is considered a single object.
- A DIFFERENCE (–) is the remaining area of Body A upon the subtraction of an overlapping Body B. It is denoted as "A – B".
- An INTERSECTION (∩) is the overlapping area of Bodies A and B. It is denoted as "A ∩ B" (or "B ∩ A").

Here is an example of a solid model created with CSG and represented with tree diagram.

Solid model	CSG within the solid model
	

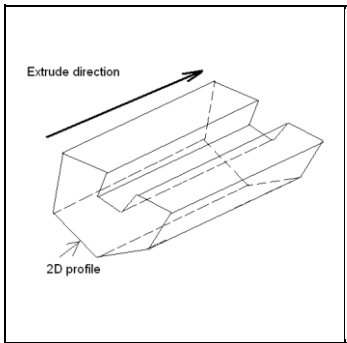
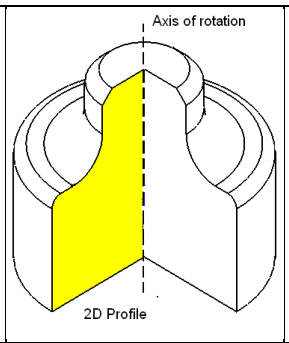
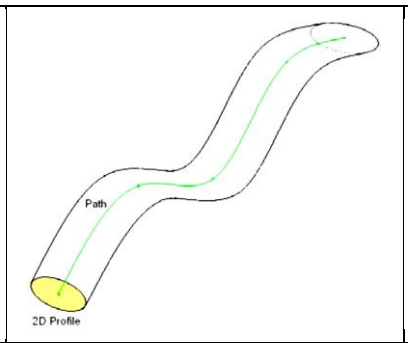
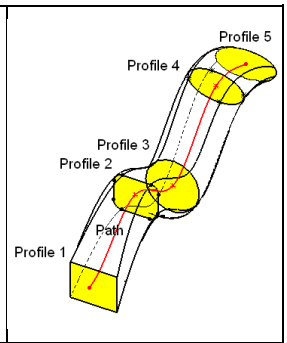
3.2.6 Feature-based modelling approach

Conceptually, the creation of a design from a 2D sketch is as follows:

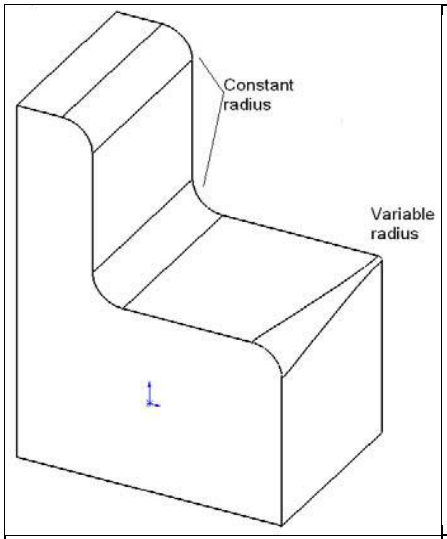
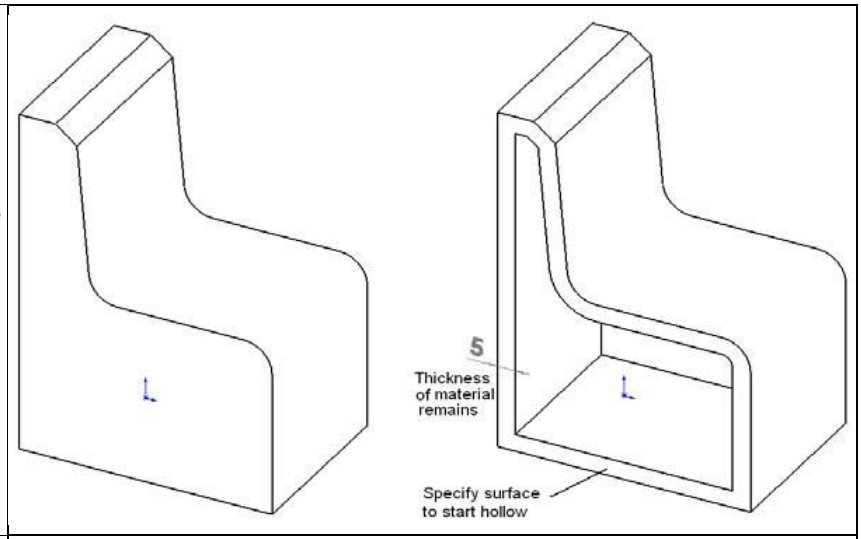


Feature-based modelling enables designers to create 3D models with shape elements which make up the physical objects. Designers only need to specify information about the features. A 'feature' means an individual shape. Some features are created by 2D profiles, while others, such as holes, fillets and chamfers, by modifying existing 3D objects.

- Creating 3D solids from 2D profiles: Extrude (linear sweeping), Revolve (rotating sweeping), Sweep (non-linear sweeping) and Loft.

			
Extrude	**Revolve**	**Sweep**	**Loft**

- Modifying existing 3D objects: Shell Feature, Fillet/Round Feature, Chamfer Feature, Draft Feature, Hole Feature, Array Feature, Mirror Feature and etc.

	
Round / Fillet Feature	**Shell Feature**

3.2.7 Advantages of 3D modelling

Compared with 2D models, 3D modelling has the following advantages:

- Allowing users to view a model from any angle
- Producing standard and auxiliary planes which are reliable
- Removing hidden lines and having realistic shading
- Checking interference
- Facilitating engineering analysis which involves finite elements
- Extracting manufacturing data for further processing
- Exporting data for animation production

3.2.8 Constraints in solid modelling

Constraints in solid modelling refer to the specified relationships among constituent primitives (e.g. being parallel).

Most CAD software applications support geometric constraints, with some basic commands as follows:

- coincident
- collinear
- intersect
- parallel
- perpendicular
- tangent

Upon the constraints are defined, a change to any entity will affect the rest.

Some simulation software application automatically sets the constraints, but most of them allow customisation or deletion by users.

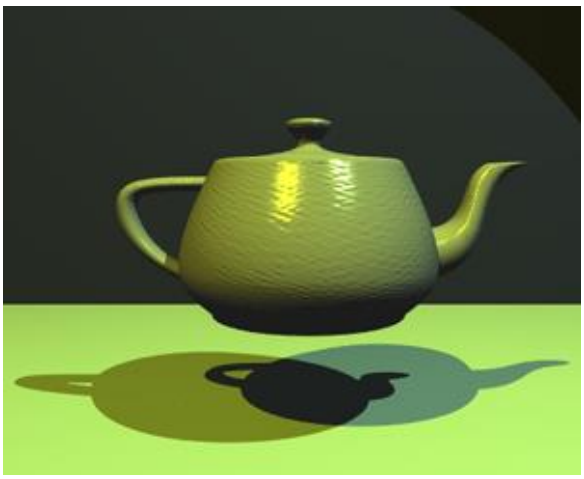


Figure 3.13 An example of 3D modelling

3.3 CAD software

CAD systems help with the design work by means of special software and devices (such as graphic displays).

In addition, CAD systems allows designers to:

1. Explore conceptual proposals
2. Create more alternative designs in a shorter time
3. Finalise designs more quickly
4. Use common databases, save the time of design data exchanges and reduce errors
5. Draw 3D models with graphics capabilities, in order to communicate design ideas and final proposals
6. Use model data of final designs for producing final design drawings

In the following sub-sections, various CAD applications and options for designers will be discussed.

3.3.1Graphic design

Graphic design combines texts and images. For example, it is used in designing logos, graphics, brochures, newsletters, posters and signs.

Various design principles (such as alignment, balance, contrast, etc.) and elements (such as lines, shapes, textures, colours, etc.) to increase the appeal and to convey messages.

Texture is the visual or surface characteristics of a design. Here are four examples of visual textures:

(a) Objects within a photograph

Texture: Crayons have fairly smooth surfaces, while cement is rough.	Texture: Both glass bottles and the potholder fabric are smooth.	Texture: These are worn mallets and grass.

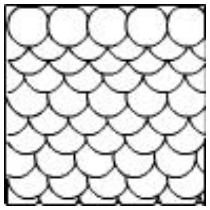
(b) Images created with photo-editing software (with simulated or imaged textures below)

Texture: Simulation of a drape or folds in a satiny fabric	Texture: Simulation of a rough and rocky surface	Texture: An imaginary texture created by random soft circles

(c) Digitised images of actual textures from scans or digital photos

Texture: A straw mat	Texture: A door mat made from old tyres	Texture: Tree barks

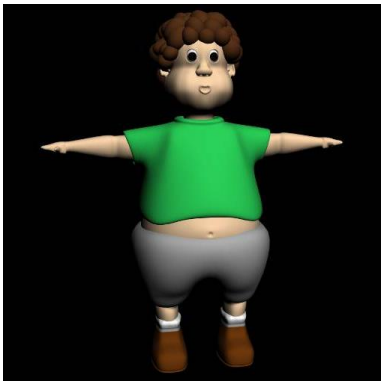
(d) Symbolic textures created with lines or shapes (various textures rendered by such patterns)

Texture: Wavy lines that symbolising water, waves or a rolling terrain	 Texture: Appearance of fish scales created with overlapping circles	Texture: Simulation of plaid or linen fabrics, wire mesh or others by means of grids of lines

3.3.2 Multimedia production

- CAD systems can be used in multimedia production for creating 2D or 3D cartoon models, animations and computer games.
- A 3D model of a human being is shown in the following pictures. It is made up of a mesh of triangles or polygons.
- If the sizes of the triangles are larger than the curvature of the body, then the sharp corners on the profile are too obvious to render a real appearance (Picture A).

(A) Coarse mesh of a 3D model



(B) Fine mesh of a 3D model

(C) Sculpture after rendering

If the sizes of the triangles are reduced greatly (Picture B), the model becomes much smoother and looks more like a real human being.

After careful rendering, the 3D model looks more like a real human being (Picture C).

Generally speaking, the smaller the triangles are used for making the model, the closer the shape of the model is to the real object.

However, when the triangles are smaller, it will take more data and calculations to create the model.

3.3.3 Interior and architectural design

Drawings of interior and architectural designs typically convey visual effects by means of perspectives, hues, shades and mirror images.

Architects often need to produce multi-view drawings for different places (such as floor and roof plans) and objects (such as furniture).

3D modelling software enables the creations of photo-realistic images and virtual walkthroughs.

Figure 3.14 A CAD software used in architectural design

Figure 3.15 A CAD software used in interior design

3.3.4 Engineering drawings

- With the help of CAD systems, engineers can design a variety of products, as large as ships, and as small as bolts or nuts.
- Before finalising the design, engineers can simulate different possibilities on the computer, such as the movement of a crank.

In addition, CAD systems can be used to:

1. Create animations to show the sequence of, for example, assembly and disassembly
2. Divide complex components into smaller and simpler design units
3. Create 3D alternatives based on existing parts/components
4. Compile 3D inspection plans
5. Enhance communication within a design team by effective transmission of information
6. Create virtual 3D models as a supplement to 2D drawings

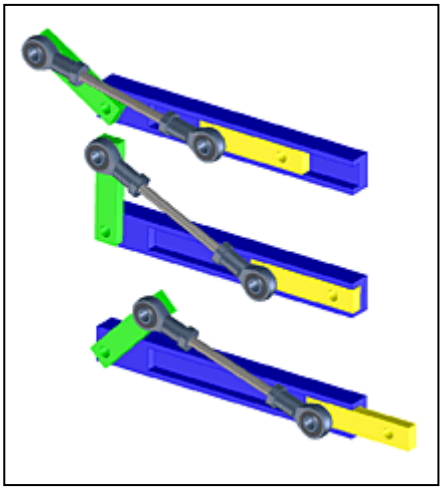


Figure 3.16 Sequence of movements in a 3D CAD system

3.3.5 Product design

Product designers often use CAD systems in order to:

1. Easily conceive and convey design ideas
2. Process product design programmes quickly and flexibly
3. Create and manage product design data or models efficiently
4. Manage the design data of existing products efficiently
5. Enhance communication within the design team
6. Facilitate management of design projects within the company
7. Simulate different views of the product on the computer prior to production

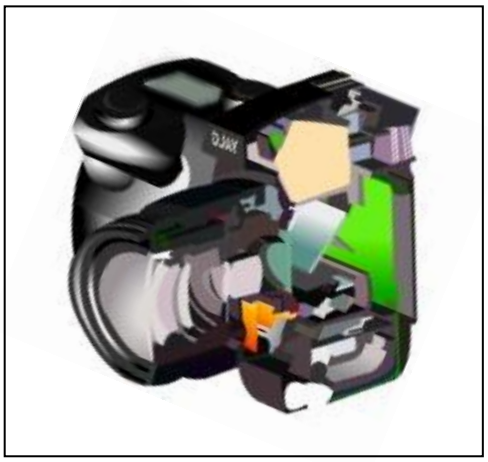


Figure 3.17 Visualisation of different views of a product on computer screen

3.4 Impact of CAD on Design Process

3.4.1 Design efficiency

With CAD systems, we can create, develop, communicate, record and convey product design information more swiftly and accurately, thus enhancing the efficiency of the entire design process.

Figure 3.18 A photo-realistic product image created by CAD

3.4.2 Quality of product images

By using CAD systems, designers are able to have a more comprehensive control over image quality, because they can:

- Select textures, such as wood against metallic patterns
- Select materials, such as reflective against non-reflective materials
- Simulate and manipulate lighting conditions and camera lens

Designers are able to create more realistic product images conveniently, and to visualise the final design.

3.4.3 Virtual products *(Also refer to Topic 3.1.1)*

- Some CAD systems enable users to observe products and their operation from different angles or distances in a virtual environment.
- Such functionality enables the demonstration of designs, mechanical devices and structures more clearly.

Figure 3.19 A virtual product demonstration

3.4.4 Automatic updating or re-drawing

- Some CAD software packages even support automatic updating and re-drawing.
- When some parts of a product are modified, other related parts are automatically updated or re-drawn, thus enhancing accuracy and efficiency.

3.4.5 Rapid prototyping (RP) *(Also refer to Topic 3.1.5)*

- RP is a solid modelling method that integrates computer modelling techniques into CAD systems.
- Once the 3D digital model is imported into an RP system, a solid model can be produced quickly.

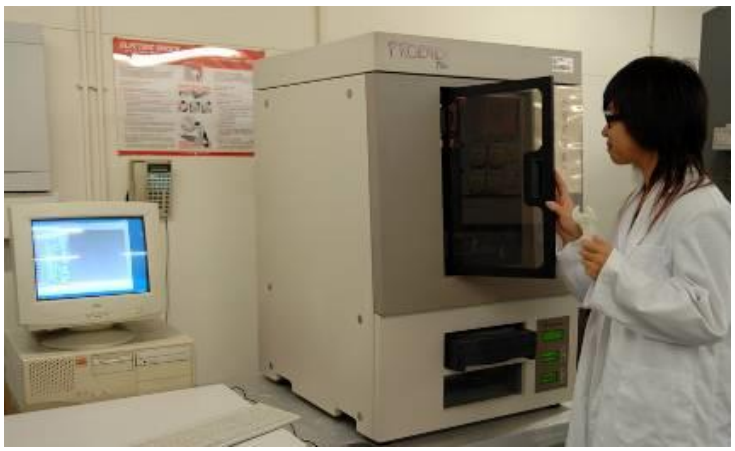


Figure 3.20 Rapid prototyping machine

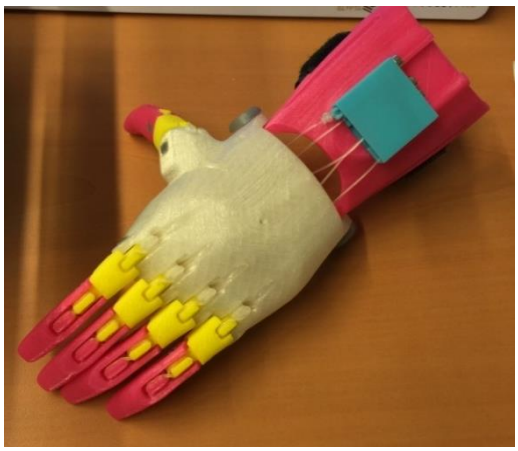


Figure 3.21 A 3D model of a robotic hand

- If a solid model or a rapid prototype is already available, the virtual prototype can be made with "stereolithography" (STL).
- Compared with the physical prototype, the virtual prototype has the advantage of saving production time and costs.

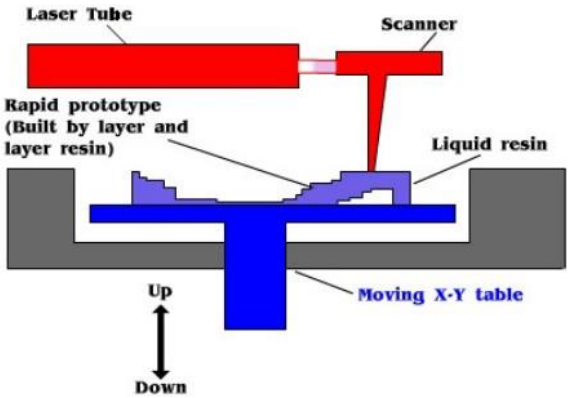


Figure 3.22 Stereolithography (STL) technology

Know More About Technology- 3D films and TV

Chapter 4 Applications

4.1 CAD and Visualisation

CAD is widely used in different industries such as construction, engineering, education, medical care and video games.

4.1.1 CAD for heritage conservation

With the 3D scanning technology, surveyors can scan historical buildings, cultural relics (such as the old Star Ferry Pier), retaining walls and slopes, and make them into 3D models for the sake of heritage protection and maintenance in future.

Figure 4.01 Surveyors scanning buildings

Figure 4.02 Three-dimensional scanning of portraits

4.1.2 3D scanned figures and objects

- 3D scanners can detect the geometric shapes and surface feature information (such as colour, reflectivity, etc.) of a real-world object, and then create a virtual 3D model of the object.
- The virtual 3D model can be conveniently processed and modified, before any re-modelling is conducted.
- Example: A person's face and head are scanned to produce a small head portrait of plastic or metal.

4.1.3 Simulation logistics systems

- The logistics design of a production line is critical to the success of a factory, so it must be taken into account carefully.
- Traditionally, the performance of a logistics system relies mainly on engineers' individual experience.
- Today, designers can use logistics simulation software and 3D animations to predict the operation of a system to prevent trouble.
- Besides, simulation software can be used to evaluate feasibility of upgrading equipment and infrastructure at a factory.

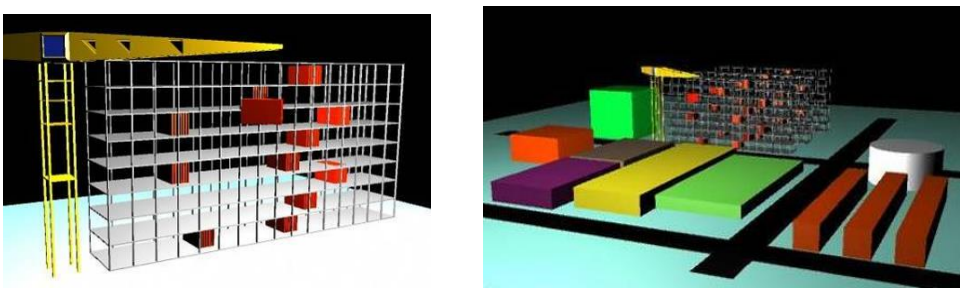


Figure 4.03 Logistics simulation at a factory

4.1.4 Mass property analysis

CAD systems can be used to conveniently calculate the mass, volume, area and other properties of a product based on the design.

Assume a bottle is made of a material of 0.92 g/cm^3.

The volume of the bottle is 4.38 cm^3 (c.c.).

Thus, the mass of the bottle is 4.38 x 0.92 = 4.03 g.

In addition, the system can calculate the surface area and other information.

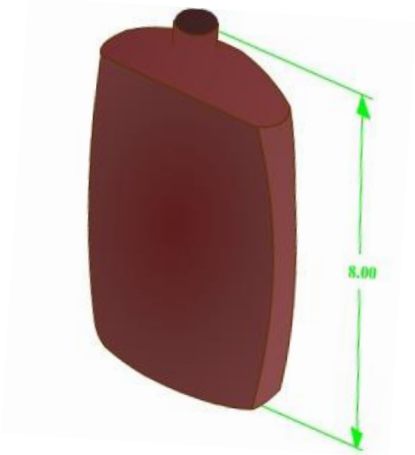


Figure 4.04 CAD calculation Volume and area

4.1.5 Virtual Reality

- Virtual Reality (VR) allows users to interact with objects in a computer-simulated 3D environment.
- Users can interact in VR by means of keyboards, mouses, specialised gloves, head-mounted displays or joysticks.
- VR can be used for training. For example, there are virtual surgeries (for training surgeons) and virtual machines (for training operators).

Figure 4.05 Virtual surgery

Figure 4.06 Pilot training with virtual flight simulator

Using VR for training features the following advantages:

(a) Trainees can develop their skills in a controlled and safe environment

(b) Training arrangements are not subject to weather or actual equipment

(c) Trainees spend less time in real training

(d) Operating costs and risks are lower than real training

4.16 VR games

- CAD can also be used to make VR games, where players can see the virtual environment and the avatars on the screen.
- Players can manipulate avatars by means of hand or motion controllers as if they were in the game world.
- VR games can become more realistic with sound effects and 3D glasses.

4.07 Hand controllers for VR games

4.1.7 Teaching

Most CAD applications can show geometries, such as 3D cubes and pyramids, on screens. Interacting with these applications enables students to understand the concepts and theories of geometries in an easier way.

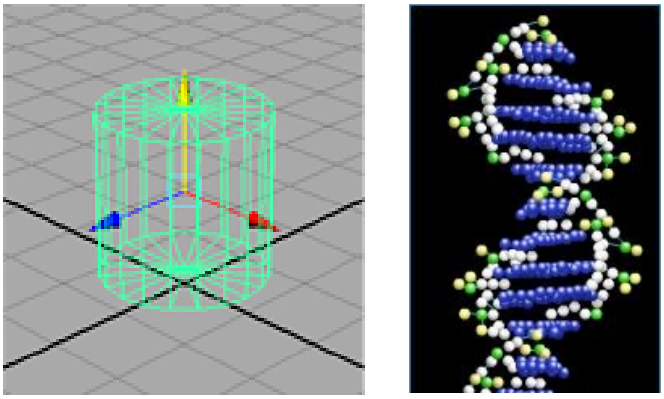


Figure 4.08 Visualisation of DNAs with CAD

CAD can assist in teaching Science subjects. For example, CAD can be used to:

(a) Simulate chemical reactions

(b) Visualise biological concepts, such as DNAs

(c) Visualise geographical shapes of particular landscapes, such as cliffs and gorges

(d) Explain spatial concepts

4.1.8 Structural analysis

- Structural analysis measures the impact of loads on the structure (stress, strain, etc.) and predicts possible damages.
- "Stress" is the distribution of forces within an object.
- "Stress intensity" is the force per unit area.
- "Strain" is the degree of deformation per unit length when a force is exerted.
- "Tensile testing" identifies the stress-strain relationship when a force is exerted and is presented with a "stress-strain curve".

A typical stress-strain curve of structural steel comprises the following parts:

1. Ultimate strength
2. Yield strength
3. Rupture
4. Strain hardening region
5. Necking region

- The appearance of the curve varies for different materials.

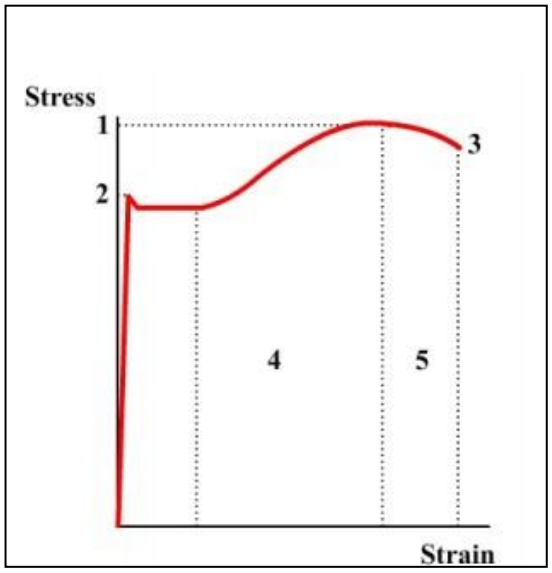


Figure 4.09 A typical stress-strain curve

- "Impact testing" measures the maximum impact a material can withstand, so as to see if the material is tough or brittle.
- Charpy and Izod are two common impact tests.

Figure 4.10 Impact testing machine

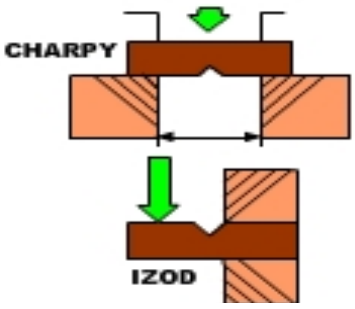


Figure 4.11 Impact testing specimen

- During the test, the impact testing machine (in the upper left picture) releases a pendulum held at a particular height to hit and break a specimen.
- In both tests, a V-shaped notch is pre-made in the lower part of the specimen to ensure rupture at the point.
- After the specimen breaks, the result is calculated based on the minimum energy required (e.g., ft lbs or KJ) and the fracture area.

4.2 Case Studies

- Theme: Dream home
- Design scenario: Living environment in Hong Kong

4.2.1 Introduction

- What is the focus of interior design after all?
- Practicality or aesthetics? Storage or space? Cutting-edge or eco-friendly? Simple or magnificent? Fashionable or retro? Natural or unique?
- During construction, we also consider other social and environmental factors and address inter-disciplinary topics, such as “resource utilisation”, “environmental protection”, “project management”, “community culture”, “building ordinance”, “personal consumption” and “social networking”.
- From the case we can understand that interior design requires not only decoration for residential purposes, but it is actually intended to meet the residents’ needs and to highlight the owner’s personality and taste.
- By making use of space, natural lighting, furniture, furnishings, lamp lights and other elements, together with appropriate colours and materials, we can create different design features and effects.

Figure 4.12 Example of home design

4.2.2 Home design considerations

- Home design aims to make the home more comfortable. However, each person’s needs are different. So are the size and partition of the house. Therefore, we need to consider the following eight factors during the design:

The needs of family members	Indoor partition and size	Facing direction of the apartment and number of windows
Locations and number of switches	**Cozy and ideal home**	Furniture and electrical furnishings
Design style	Restrictions	Safety

4.2.3 Unique home design

- Home design is intended to not only address actual needs, but hopefully also be unique and show the owner’s personal taste. Therefore, we need to consider the theme of design at first. For example:

1. Simple and practical
2. Simple and stylish
3. Noble and elegant
4. Green home
5. Smart home
6. Modernism
7. Local features
8. Vintage design
9. Thematic design
10. Universal design

4.2.4 Design brief and production considerations

- Design and create an ideal / dream home model for yourself or your family.
- After moving to a new house or having found a suitable house, you should firstly understand the design limitations of the flat and the needs of your family members. In view of individual needs and the size of the house, the following eight factors should be taken into account during the design:

1. The needs of family members: Everyone has their unique requirements in life, so you should firstly understand their needs
2. Indoor partition and size: The number and the aspect ratios of rooms have direct effects on the entire interior design
3. Facing direction and number of windows: An ideal house should feature more natural lighting and fresh air
4. Locations and number of switches: Switches should be located near electrical appliances to avoid exposure of wires
5. Arrangement of furniture and electrical appliances: Their proper arrangement can ensure the efficient use of space
6. Design style: Each unique design style shows the owner's taste and personality
7. Restrictions: Some elements should be left intact, such as the load-bearing walls, the ceiling height, the facing direction of the unit, the number of windows, the location of the main door, and the number and sizes of bay windows, to which special attention should be paid during the design
8. Safety: Building structure and fire safety are essential considerations

4.2.5 Materials and tools for modelling

- Typical CAD and CG software packages:
  - CAD: AutoCad, JwCAD (Freeware), ArchiCAD
  - CG: SketchUp (Freeware), Interior Designer Neo, 3DS Max
- Cardboard, styrofoam, wood, acrylics, etc.
- Finishing: Painting, poster colours, coloured paper
- Bonding methods: Adhesive tapes, white glue, contact glue, hot glue gun, steel nails, screws, all the following hand tools and machines
- Cutting tools: Laser cutting machine, coping saw, jigsaw, band saw, file, sanding machine, drilling machine
- Portable tools: Electric drill, electric screwdriver, jigsaw

4.2.6 Documents of technical visualisation

- Floor plan (original design with dimensions)
- Floor plan (modified design with dimensions)
- Layout plan of interior furniture and large appliances
- Layout plans of alternative furniture arrangements (showing different design ideas)
- Interior electrical plan
- Indoor perspectives (different corners)
- Top view (the whole unit or a certain corner)
- Sectional 3D model (computer simulation or scale model)

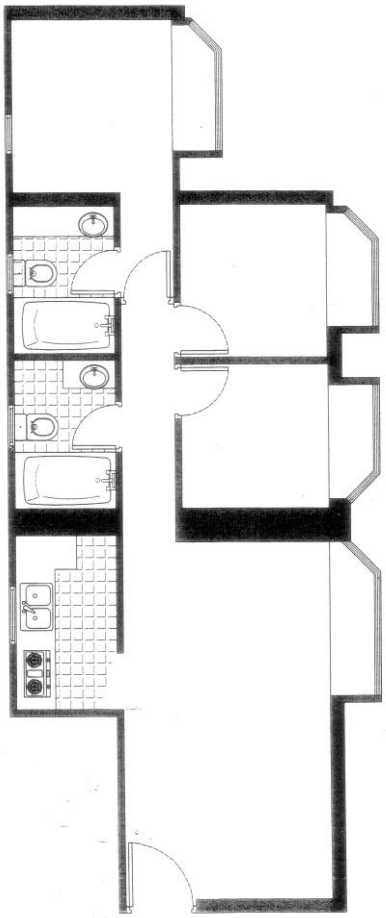
4.2.7 Design brief

- Design and create an ideal / dream home model for yourself or your family, based on the merits and restrictions of the unit, as well as the habits and needs of yourself and your family.
- Use relevant design techniques and CAD applications such as:
  - 2D and 3D drawing techniques
  - Solid / virtual modelling techniques
  - CAD and CG software packages
- Choose the appropriate approach. Create the model and design the presentation board to show your ideal home design.

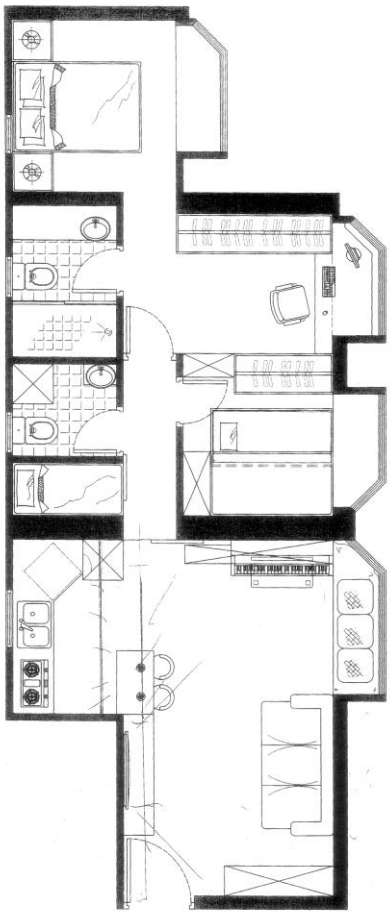
4.2.8 Examples of floor plans

- Interior floor plans:

(Figure 1) is the original floor plan of a unit. (Figure 2) shows the partition, as well as the arrangements of rooms, furniture, electrical appliances and light troughs, based on the design.



(Figure 1)



(Figure 2)

4.2.9 Examples of CAD drawings

- CAD floor plan with furniture and appliances

- 3D CAD drawings

Know More About Technology

Virtual reality head-mounted display

Hand-eye coordination in virtual reality

Virtual Reality parachute training