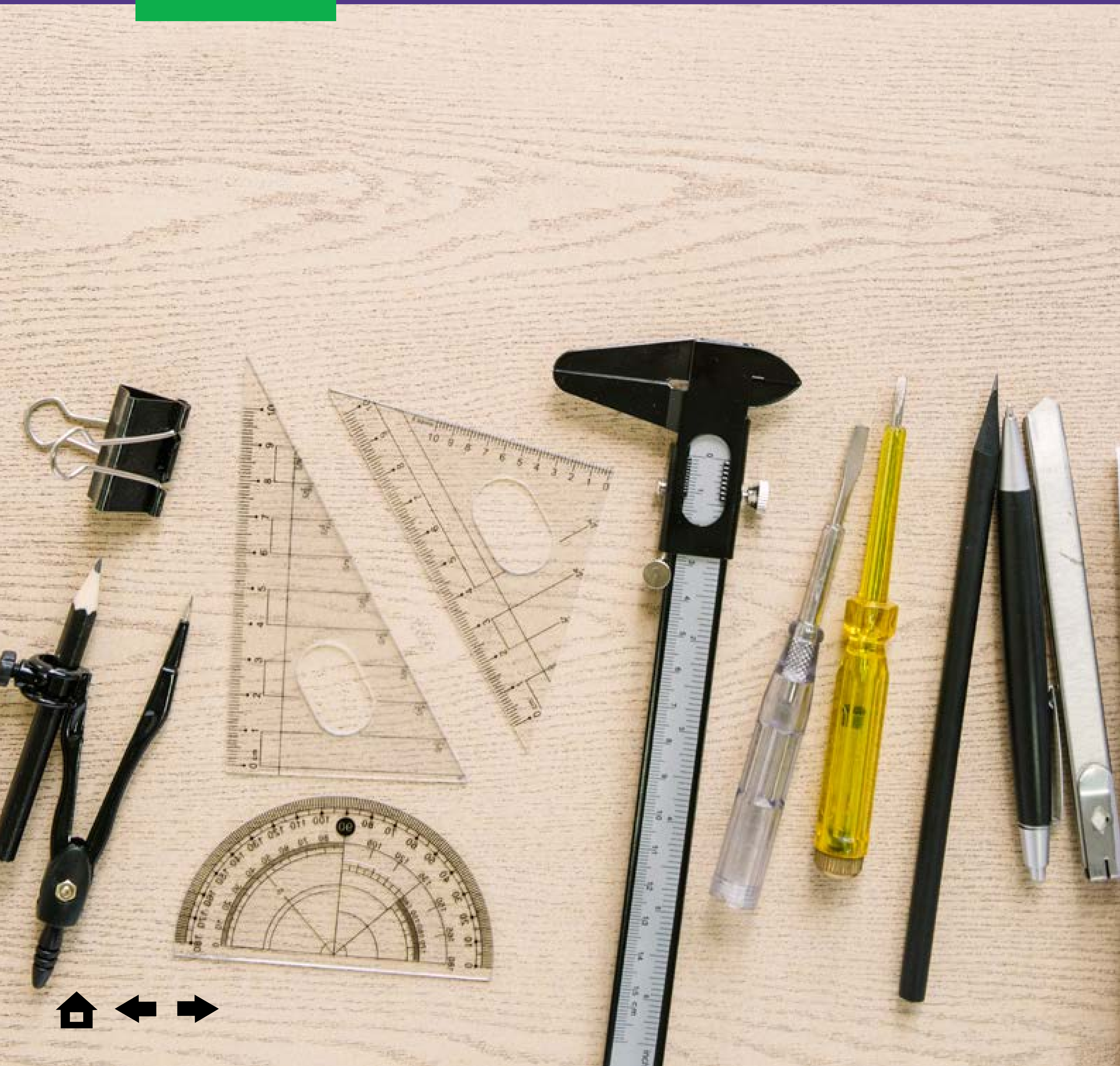
Manufacturing Engineering

Year 1

SECTION

3 UNDERSTANDING MATERIALS



DESIGN AND PROTOTYPING

Design and Drawing for Manufacture

Introduction

Dear learner, welcome to another exciting section. In this section, we shall learn about drawing instruments and their application. Drawing instruments refer to essential tools used by artists, architects, engineers, and designers. They are used to prepare drawings easily and accurately. The accuracy of the drawings depends largely on the quality of instruments. With instruments of good quality, desirable accuracy can be attained with ease. It is, therefore, essential to procure instruments of as superior quality as possible. They range from basic tools like pencil, set-square, a pair of compasses, protractor, a pair of dividers, ruler, French curves, drawing board, T-square and drawing sheet/ paper.

Additionally, we shall learn to develop the surface of models for manufacturing. When you look at tin cans, you can see that the cylindrical part is rolled and joined together to form the cylinder shape. The size and the shape of the material used to make the cylinder is made possible by the application of surface development. It involves unfolding or unrolling the 3D surface or object to create a flat, 2D representation that can be used as a template for manufacturing, design, or other applications. The development of an object is therefore, the shape of a plain figure that by proper folding can be converted to the shape of the solid figure. It shows the true size of each area of the object.

We will further delve into how these products are designed from scratch or are improved to solve a particular challenge identified in the existing products. The design process is a systematic approach used to create products that meet specific technical requirements as well as economic, social and legal considerations. It involves a series of stages that ensures that an initial idea (solution or concept) is nurtured into a more useful solution (conceptual design) that could be used to produce a tangible and marketable product in the future. A well thought through design process should produce a simple but useful product design that would have low material cost and low manufacturing cost to solve that complex problem.

Finally, we will learn about the importance of freehand sketching and visualisation of objects. Freehand sketching refers to the method of drawing or sketching without the use of measuring tools such as rulers, pairs of compasses, or templates. It involves using only the hand and eye coordination to create sketches directly on paper. Visualisation involves creating visual representations of ideas and concepts to help designers understand how they will look and function in the real world. Visualisation can take many forms, including sketches, diagrams, models, and prototypes.

At the end of this section, you will be able to:

- Demonstrate the use of drawing instruments in product design.
- Develop the surfaces of models for manufacturing
- Demonstrate understanding of the design process
- Demonstrate the importance of free hand sketching and visualisation of
- objects in the design of products

Key Ideas

- **Drawing instruments** are specialised tools that are used by engineers, architects, designers and other professionals to create accurate and precise drawings, diagrams, sketches and plans. These instruments are used to create accurate and detailed drawings of designs.
- **Surface development** is a geometric concept used to transform 3D objects into 2D patterns. It involves unfolding or unrolling a complex 3D surface or object to create a flat, 2D representation that can be used as a template for manufacturing, design, or other applications. The knowledge of this is useful in manufacturing of sheet metal products and other design products. The methods of surface development include parallel line, radial line, triangulation and approximate development.
- **The design process** is a step-by-step decision making process to conceive an idea that could be used to create a product for solving a problem in society. The idea usually depends on the designer's imagination ability and one's willingness to intentionally and critically think about how a problem could be solved. This intentional and critical thinking process that would lead to possible solutions to the problem is called brainstorming.
- **A good brainstorming session** is one that is usually guided by some design or research questions and would lead to useful solutions called conceptual designs. These questions are very important in ensuring that at least the conceptual designs meet some requirements.
- **The best conceptual design** is usually developed into a model product called a prototype.
- **Freehand sketches** are a quick and easy way to capture ideas and concepts on paper and are often used in the early stages of the design process to help engineers (designers) visualise their ideas and communicate them to others.
- **Visualisation** involves creating visual representations of ideas and concepts to help designers understand how they will look and function in the real world.

USING DRAWING INSTRUMENTS IN PRODUCT DESIGN

Now let's describe each of the above instruments in detail with their uses.

Pencils

Pencils are used to draw different lines, shapes, symbols and to write texts in engineering drawing. The accuracy and appearance of a drawing depends very largely on the quality of the pencils used. With cheap and low-quality pencils, it is very difficult to draw lines of uniform shade and thickness. Based on the hardness of lead, pencils are classified into three major grades as hard, medium and soft. The pencils used for technical drawing differ in some ways from ordinary pencils. They are available in a range of hardness levels, from 9H (hardest) to 9B (softest). Pencils to be used for drawing purposes must be sharpened to a chisel edge, kept sharp to ensure clarity of drawings. Great care should be taken in mending the pencil and sharpening the lead, as the uniformity in thickness of lines depends largely on shape of the lead of the pencil. The lead may be sharpened to two different forms:

- Conical point and
- Chisel edge.

The conical point is used in sketch work and for lettering and shading, while the chisel edge is used for construction. Table 3.1 shows the type of pencils used in engineering drawing and their uses.

Table 3.1: Type of pencils and their uses.

Type of pencil	Uses
B	Soft-grade pencil used for shading, lettering and free hand sketching.
HB	Medium grade pencil used for lettering, visible outlines, visible edges, free hand sketching and boundary lines.
H	Hard grade pencil used for construction lines, dimension lines, leader lines, extension lines, centre lines, hatching lines and hidden lines.
2H	Very hard-grade pencil used for graphic and technical drawing.

Set squares

Transparent celluloid/Plastic set squares are preferred and are commonly used rather than ebonite ones. They are triangular rulers used to draw angles and perpendicular lines. Fig. 3.1 is a picture of set squares used in engineering drawing. Set squares are commonly used to construct the most common angles (i.e. 30^0, 45^0 and 60^0) in technical drawings. They are also used to draw parallel and perpendicular lines easily and conveniently.

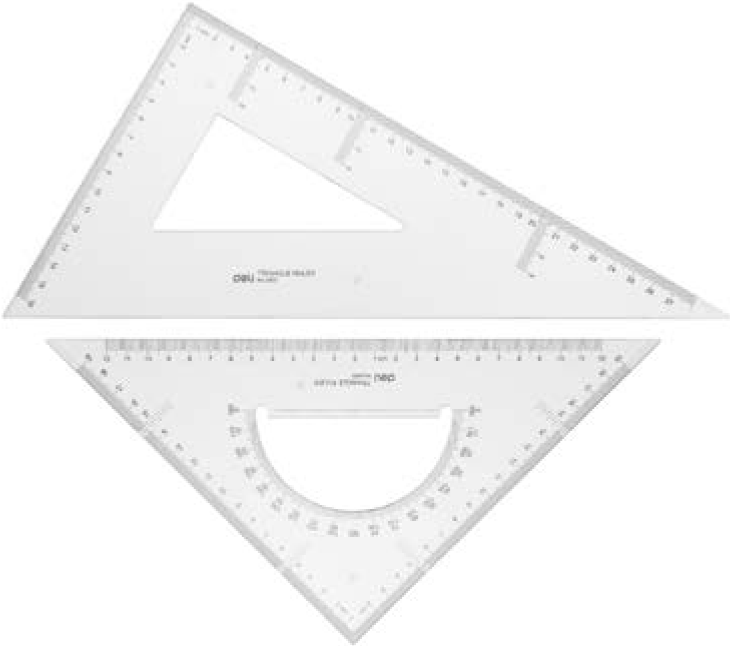


Fig. 3.1: Set squares

A Pair of Compasses

This is an instrument used to draw circles and arcs. It consists of two legs pivoted at the top. One leg is equipped with a steel needle attached with a screw, and other shorter leg is, provided with a socket for detachable inserts. Fig. 3.2 is an example of a pair of compasses

Fig. 3.2: A pair of compass

Protractor

A protractor is made of wood, tin or celluloid. Protractors of transparent celluloid are in common use. They are flat and circular or semi-circular in shape. The most common type of protractor is semi-circular and of about 100mm diameter. Its circumferential edge is graduated to 1° divisions, is numbered at every 10° interval and is readable from both the ends. The protractor is used to accurately draw or measure angles that cannot be drawn with set squares. Fig. 3.3 is an example of a protractor.

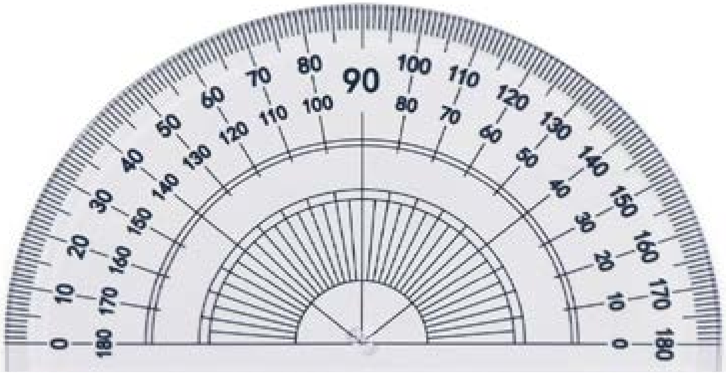


Fig. 3.3: Protractor

A Pair of Dividers

A pair of dividers is an adjustable tool with two pointed legs. Dividers with adjustable joints are preferable rather than plain legs. It is mainly used to transfer dimensions and dividing lines and circles into a number of equal parts. Fig. 3.4 is an example of a pair of dividers.

Fig. 3.4: A pair of Dividers

Ruler

This is a basic tool used in conjunction with the T-square to draw horizontal lines. It is also used to measure dimensions or distances accurately. It helps to ensure the precision and clarity of drawings. Fig. 3.5 is an example of a ruler.

Fig. 3.5: Ruler

French curves

French curves are curved templates used to draw complex curves that are challenging to create with regular drawing tools. An example of a French curve is shown in Fig. 3.6.

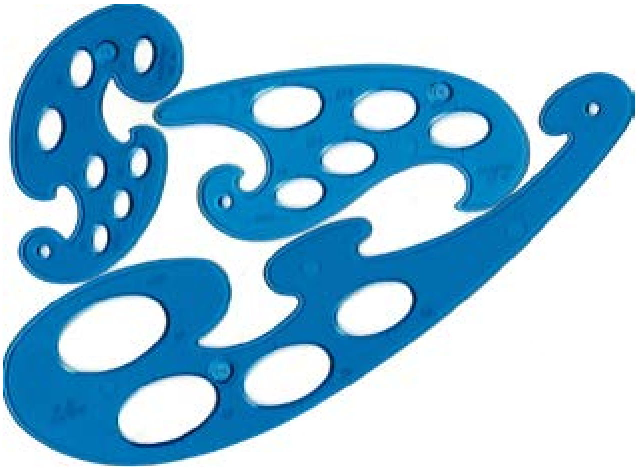


Fig. 3.6: French curve

Drawing board

A drawing board is a flat, portable surface used to support a paper or drafting sheet during the drawing process. Fig. 3.7 shows a drawing board. Drawing boards are made in various sizes. Their selection depends upon the size of the drawing paper to be used. The sizes of drawing boards recommended by the (ISO 216) are tabulated in table 3.2. For use in schools and colleges, the last two sizes of the drawing boards are more convenient. Large size boards are used in drawing offices of engineers and engineering firms.

Table 3.2: ISO 216 Recommended Drawing Board Sizes.

S/N	Designation	Sizes (mm)
1	A_0	1270×920
2	A_1	920×650
3	A_2	650×450
4	A_3	450×320

Fig. 3.7: Drawing board

T-square

A T-square is made up of hard-quality wood. It consists of two parts - the stock and the blade - joined together at right angles to each other by means of screws and pins. The stock is placed adjoining the working edge of the board and is made to slide on it as and when required. The blade lies on the surface of the board. Its distant edge which is generally bevelled, is used as the working edge and hence, it should be perfectly straight. Now-a-days a T-square is also available in celluloid or plastic with engraved scale. The T-square is used to draw horizontal lines and to align other drawing instruments on the drawing board. It is also used in conjunction with the set square to draw vertical lines. Fig. 3.7 shows a drawing board with a T-square.

Fig. 3.8: T-square

Drawing sheets

The A series drawing sheets are mostly used in technical drawing. These drawing sheets come in different sizes as shown in Table 3.2 and Fig. 3.9. Drawing sheets can be laid out in drawing boards in landscape (viewed with the longest side horizontal) or portrait (viewed with longest side vertical) form. When using A0 to A3 drawing sheets, only landscape form of layout holds.

Table 3.3: Sizes of A-series drawing sheets.

Drawing Sheet	Trimmed Sheet (mm)	Drawing Field (mm)
A0	841 × 1189	831 × 1179
A1	594 × 841	584 × 831
A2	420 × 594	410 × 584
A3	297 × 420	287 × 410
A4	210 × 297	200 × 287

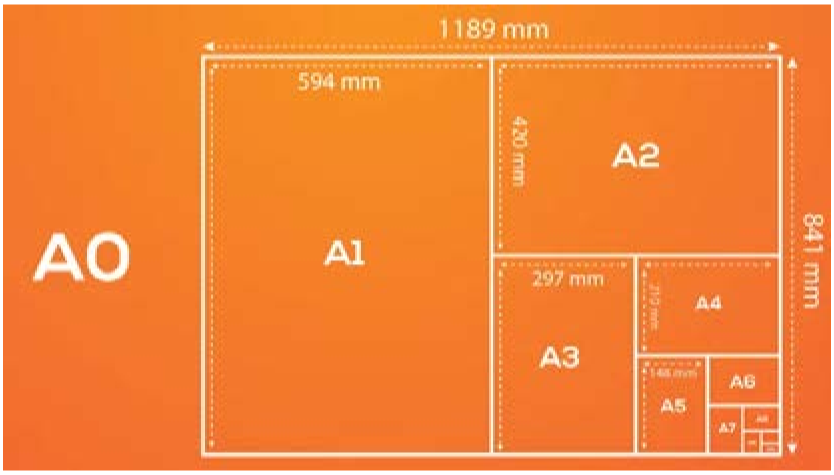


Fig. 3.9: Sizes of A-series drawing sheets

Layout of drawing sheet

A blank drawing sheet to be used for any drawing contains borders enclosed by edges of trimmed drawing sheet, title block, frame limiting the drawing space and centring marks, as shown in Fig. 3.10.

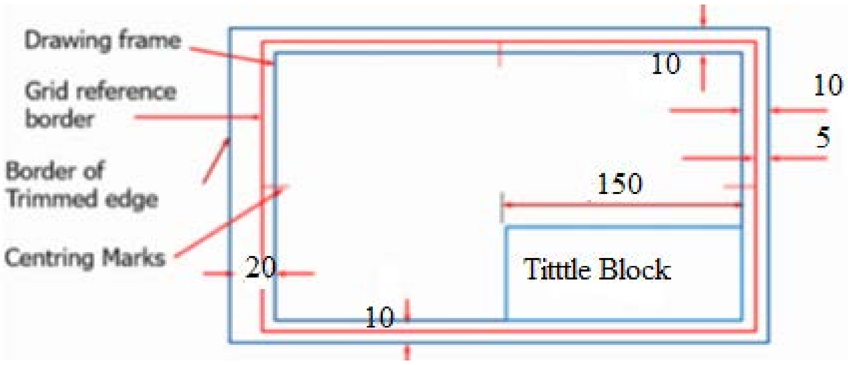


Fig. 3.10: Layout of drawing sheet (dimensions in mm)

Setting out a drawing sheet on a drawing board.

The following techniques can be used to set out a drawing sheet on a drawing board:

1. Place drawing paper on board
2. Place T-square on paper
3. Align the head of T-square to the effective edge of the board
4. Align the top edge of the paper to the horizontal effective edge of the T-square
5. Slide the T-square slightly down and clip the exposed upper edge of the paper to the board

Title block

The title block is located at the bottom right-hand corner of the drawing space and contains basic information such as the name of the company or organisation, the title of the drawing, drawing number, scale, date with the name of the staff who designed, drew and checked the drawing, method of projection. Fig. 3.11 is a sample Title block that can be used for drawings (all dimensions are in mm).

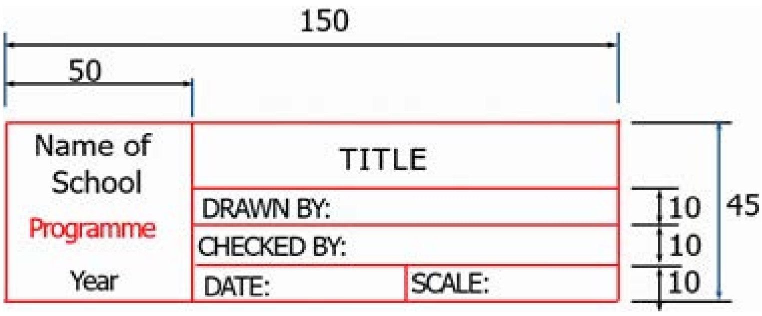


Fig. 3.11 : A sample Title block

Activity 3.1

In this activity, we will be exploring drawing instruments and their uses

Equipment needed: pencil, set-square, a pair of compasses, protractor, a pair of dividers, ruler, French curves, drawing board, T- square and drawing sheet/paper. Follow the steps below to complete this activity.

1. Take your time to familiarise yourself with each drawing instrument and note down their names and primary functions.
2. Pick a drawing sheet, spread it on the drawing board and hold it firmly onto the drawing board with a clip.
3. Select one instrument at a time and demonstrate its proper use.
4. Pick a ruler and use it for drawing straight lines and measuring distances accurately.
5. Select a pair of compasses and a protractor for creating circles and angles.
6. Practice sketching with different pencil grades to observe their effects on texture and shading.

7. Explore different drawing instruments such as the French curve, Tee square, set squares on the drawing board to familiarise yourself with their uses.
8. Experiment with different techniques to understand how each instrument can be used differently.
9. Summarise your experience with the drawing instruments and present the applications of each instrument in a write-up as an assignment.
10. Consider sharing your work and experiences with peers or mentors to receive constructive feedback and improve your skills.

We hope you enjoyed this activity. Let us go through activity 3.2 for mastery of our skills.

Activity 3.2

Now that we are familiar with the drawing instrument, let us now set-up our drawing sheets on a drawing board and use the drawing instruments to create some drawings.

Equipment needed: pencil, set-square, a pair of compasses, protractor, a pair of dividers, ruler, French curves, drawing board, T-square and drawing sheet/paper.

Steps:

1. Place drawing board on a sloppy table
2. Place T-square on paper on the board
3. Align the head of the T-square to the effective edge of the board
4. Align the top edge of the paper to the horizontal effective edge of the T-square
5. Slide the T-square slightly down and hold the exposed upper edge of the paper firmly onto the drawing board
6. With the help of a ruler and pencil, draw border lines around the edges of the drawing paper, leaving a margin of about 10mm from the edges to create a neat frame for the drawing
7. With the help of a ruler, a pair of dividers and a pencil draw a title block at the right corner of the drawing sheet measuring 150mm× 45mm, include fields like name of company or organisation, the title of the drawing, the drawing number, scale, date with the name of staff who designed, drew and checked the drawing, method of projection
8. Use a pair of compasses to draw circles of different sizes
9. Use a protractor for drawing and measuring angles
10. Use a T-square with a ruler and set squares, to draw horizontal and vertical lines for squares and rectangles
11. Reflect on the process of setting up the drawing sheet and using various drawing instruments for mastery

We hope you enjoyed this activity!

Now, set up your drawing sheet and construct a circle, an equilateral triangle, a square, and a rectangle. Sharing your work and experiences with peers or mentors to receive constructive feedback and improve your skills.

Activity 3.3

Take turns as directed by your teacher to teach a lesson on the effective use of drawing instruments in product design.

PRINCIPLES OF SURFACE DEVELOPMENT

Surface development is a geometric concept used to transform 3D objects into 2D patterns.

Importance of Surface Development

Surface development is an important concept in product design and manufacturing especially in sheet metal work. Products such as boilers, chemical vessels, storage vessels and chimneys are manufactured using the principle of surface development by cutting plates and bending them into their desired shapes. Surface development is important because:

1. It enhances understanding of the design by both the designers and the manufacturers.
2. It prevents wastage of materials during manufacturing.
3. It streamlines the production of parts.
4. Complex shapes are accurately represented.

Methods of Surface Development

Developing a surface for manufacturing is done based on the shape of the object, some objects are simple to develop while others are complex and involve more work and skill. The various methods for developing a surface are parallel line development, radial line development, triangulation development and approximate development. Let us now dive further into these methods.

Parallel Line Development

Parallel line development uses parallel lines to construct the expanded pattern of a three-dimensional shape. In this method, we will divide the surface into a series of parallel lines to determine the shape of the pattern. We can use this method in the development of prisms and cylinders. Figure 3.12 shows the development of a 3D object using parallel line methods, objects such as tin cans, boilers and metal pipes are manufactured by applying the principles of parallel lines on a sheet of metal.

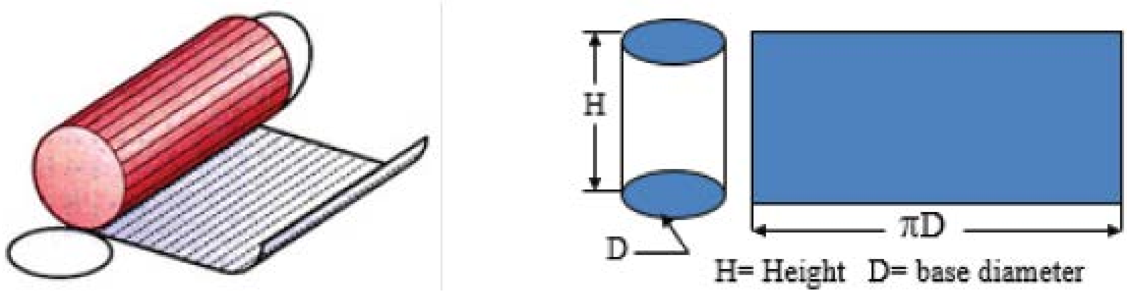


Fig. 3.12: (a) Development of a cylinder using parallel line method (Source: Teachers manual)

Radial Line Development

Radial line development is done by drawing a constructional line from a central point to the expanded part of a three-dimensional shape to form a pattern. The lines forming the pattern diverge from the central point to the base of the shape. We use this method mostly in the development of cone and pyramid as can be seen in Figure 3.13. The principle of radial line development is used in the making of umbrellas and silos.

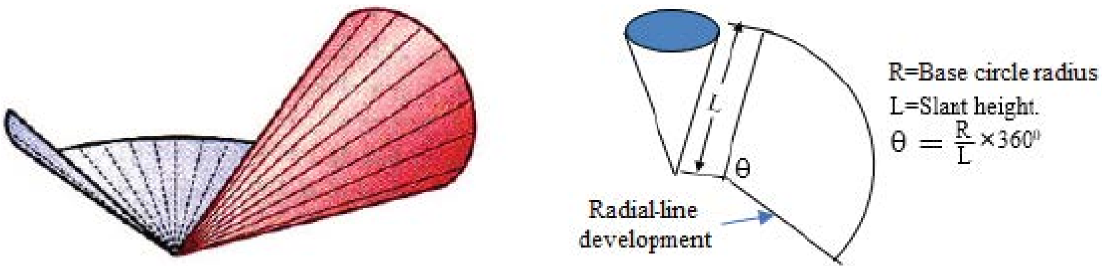


Fig. 3.13: Development of a cone using radial line method (Source: Teachers Manual)

Triangulation Development

This method involves dividing the 3D object into small triangles and then flattening them into a 2D pattern. These developments are made from tetrahedrons, polyhedrons, single-curved surfaces and wrapped surfaces as can be seen in Figure 3.14. Triangulation development enables accurate and efficient creation of complex shapes such as the one shown in Figure 3.14 if smaller and more numerous triangles are used.

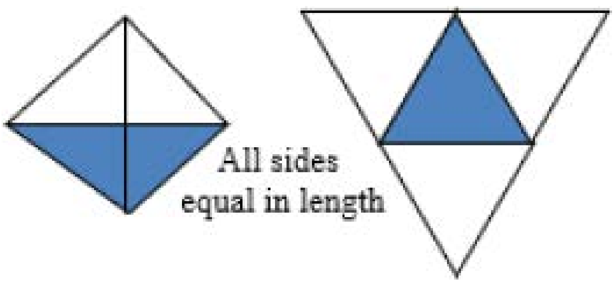


Fig. 3.14a: Development of a tetrahedron using triangulation method.

Fig. 3.14b: Triangulation method is used for complex shapes.

Approximate Development

We use approximate development for the development of complex surfaces that are difficult to develop. This method produces only an approximation of the original shape. This means that the surfaces developed from this method are less accurate because the part is stretched or distorted to obtain the final. Figure 3.15 shows the use of this method in the development of spheres.

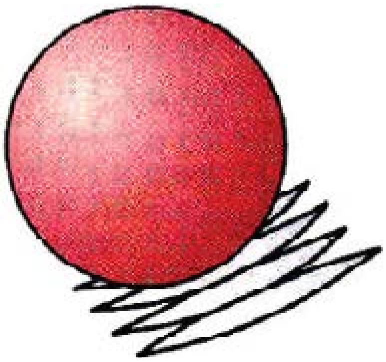


Fig. 3.15: Development of a sphere using approximate method.

Application of Development of Surfaces

We can use the knowledge of surface development in the production of parts from sheet metals. In the workshop, a welder making a coal-pot will first create a pattern using surface development principles. They will then cut them before welding the part together to create the coal-pot.

In fashion, a tailor will first prepare a surface development on a cloth (pattern) to cut and stitch the correct shape and size to form a shirt.

Other applications include architectural, and engineering industries where products like utensils, cans, buckets, hopper, domes, aircraft fuselage, fuel tanks, clothes, furniture, and packaging.

Activity 3.4

Use the links below to watch videos on the principles of surface development in manufacturing of a product.

- https://youtu.be/rKsmsRq5Pfs
- https://youtu.be/V5BRnzwUJYI
- https://youtu.be/ZVqQVwhJQaA
- https://youtu.be/Vl7Tvy8qHE4
- https://youtu.be/L5Ac7CgVOzY

Activity 3.5

Now that you have watched the videos, and with guidance from your teacher, write a brief report on the different methods of surface development discussed in the videos. Use the points below to guide you in writing your report.

1. Title (A report on the different methods of surface development)
2. Method 1 (example; Triangulation)
3. Explain the method with the use of diagrams
4. Explain some applications of the method
5. Explain the importance of the method
6. Repeat point 2 – 5 for all other methods
7. Conclusion

Activity 3.6

In this activity, we will look at the surface development method used to make packaging boxes. We will need empty boxes to perform this exercise, so before we start with the activity, collect two empty boxes from your house or the community.

Now that we have the boxes, let us begin our activity by following the steps below.

Step 1: Look for adhesive tapes that hold the box together and remove them

Step 2: Unfold the box

Step 3: Cut one edge of the box

Step 4: Flatten the box and place it on a table

Step 5: Sketch the pattern created by the box onto an A4 sheet and identify the surface development method used for making the box

Step 6: Use the lines on the edges of the box to fold it back into a box

Activity 3.7

We will now use our knowledge from Activity 3.7 to create a box by drawing the development of a square prism. A piece of cardboard and a paper cutter will be required for this exercise.

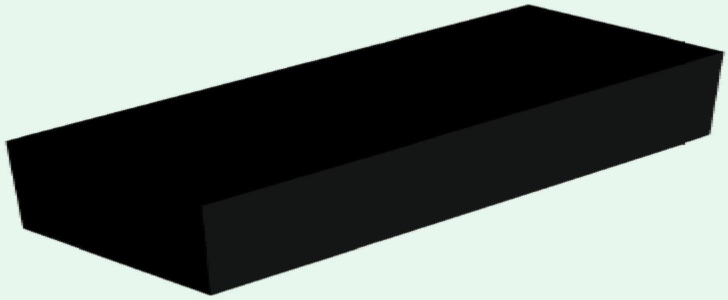


Fig. 3.16: A prism

Step 1: Draw the front and top view of the prism as shown below on your cardboard in centimetres

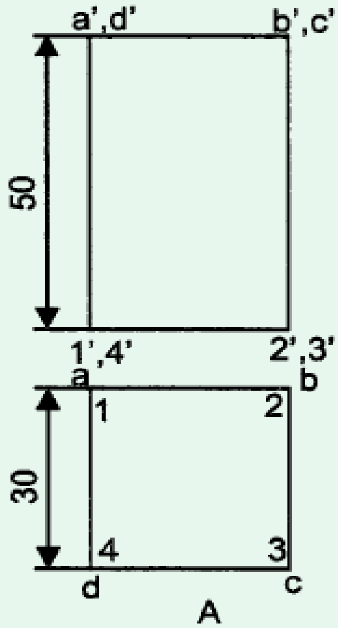


Fig. 3.17: Front and top view of a prism

Step 2: Now let's draw the stretch out line of the prism with equal length to the circumference of the prism to form the figure below. This means the length must be equal to the length of (|ad| + |cd| + |bc| + |ab|) = 120cm

Step 3: Label the diagram as shown in figure 3.18.

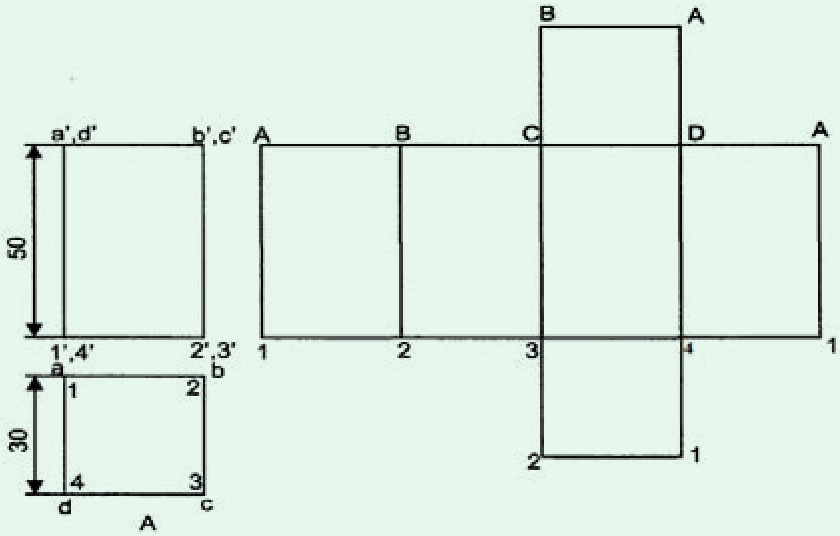


Fig. 3.18: Surface development of a prism (Venkata, 2008)

Step 4: Now let us cut out the edges of the developed surface as shown below in Figure 3.19. Be sure to cut along the path A-B-C-B-A-D-A-1-4-1-2-3-2-1-A

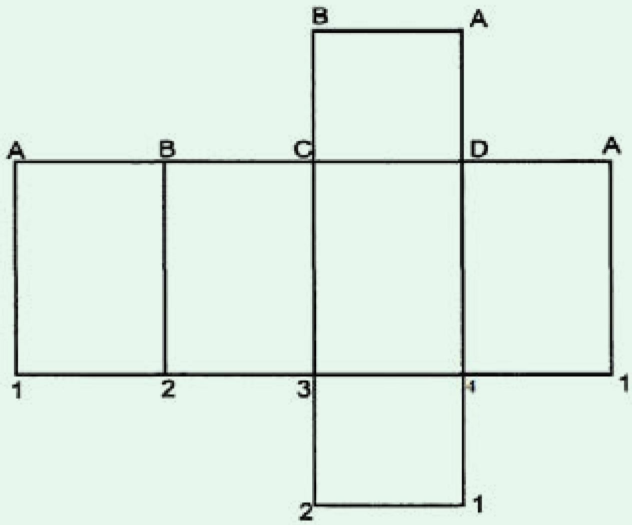


Fig. 3.19: The development to be cut-out for making of the box (Venkata, 2008)

Step 5: Fold the drawings along the edges of the lines drawn to create a box

Step 6: Compare your work with a colleague and discuss the process and ways to create other kinds of boxes

Activity 3.8

In a group of three, let us now create a cone using cardboard as our material. We will follow the steps below to create the development of a cone.

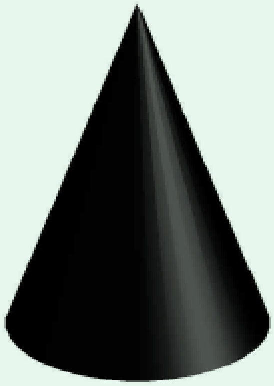


Fig. 3.20: A cone can be developed using radial line development

Let us follow the steps below to create our surface development.

Step 1: Draw the base of the cone as a circle with diameter 40mm

Step 2: Draw a horizontal line |as| through the centre 'O' to form the diameter of the circle

Step 3: Draw a horizontal line at 5 mm above the circle

Step 4: Draw a perpendicular line to |as| from O to the horizontal line above the circle and label the point as **b**. Draw perpendicular line from point **a** and **s** to the same horizontal line and label as **a'** and **s'**

Step 5: Extend the line at point **b** vertically by 40mm to point **o'**

Step 6: draw a line from point **a'** and **s'** to point **o'**

Step 7: Let us now calculate the angle, subtended by the circumference of the base

Angle, $= 360° \times$ (radius/o's')

|o's'| is the true length of the cone and is measured to be 45mm

Angle, $= 360° \times (20/45)$

Angle, $= 160°$

Now that we have done the projection and know the value of our true length, let us develop the surface of our cone

Step 8: Draw two lines of length 45mm at 160º from each other emerging from a point labelled O. Label both ends of the line as A

Step 9: Using point O as your centre, draw an arc that connects the two ends of the lines

Step 10: Extend the line at point A by 20mm and draw a circle of radius 20mm at the end point

Step 11: Cut out the developed surface along the line A-A-O-A (the upper part of the cone) and the circle (base)

Step 12: Fold the upper part of the cone and place it on the circle

We now have our cone.

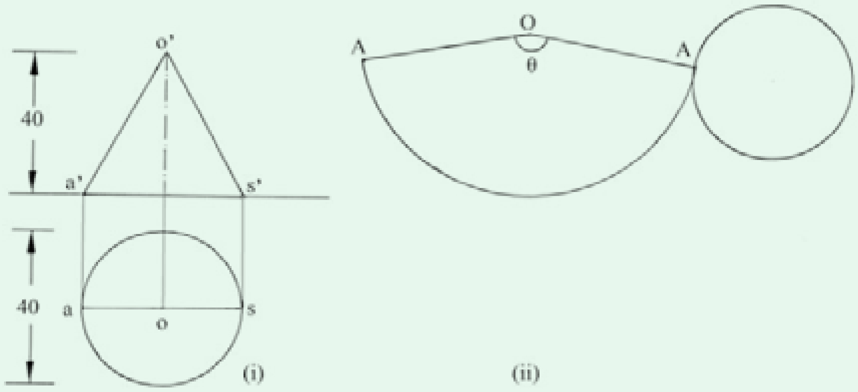


Fig. 3.21: Development of a cone using radial (Rathnam, 2018)

Activity 3.9

Now that we have created a cone let us develop our skill further by creating a cylinder using a piece of cardboard.

Fig. 3.22: A picture of a cylinder

Let us follow the steps below to create our surface development.

Step 1: Draw the base of the cylinder as a circle with diameter 30mm

Step 2: Draw a horizontal line |as| through the centre 'O' to form the diameter of the circle

Step 3: Draw a horizontal line at 5mm above the circle

Step 4: Draw perpendicular line to |as| from point **a** and **s** to the horizontal line above the circle and label as **a'** and **s'**

Step 5: Draw a horizontal line 50mm from line |a's'|

Step 6: Draw perpendicular lines from point **a'** and **s'** to the line at 50 mm away to create a rectangle

Let us now calculate the length of the rectangle which is representing the development of the lateral surface of the cylinder and is equal to the circumference of the base, πD. Where D is the diameter of the circle

Circumference = $\pi \times 30$mm

Now that we have done the projection and know the length of the rectangle, let us develop the surface of our cylinder.

Step 7: Draw two horizontal and parallel lines of length πD and 50mm from each other

Step 8: Connect the ends of the two lines with two perpendicular lines

Step 9: Extend the line at point 1 by 15mm and point 2 by 15mm

Step 10: Draw a circle of radius 15mm both end points to form the top and bottom base

Step 11: Cut out the developed surface along the line 1-2-3-4-1 (the rectangular part of the cylinder) and the tow circles

Step 12: Fold the rectangular part to form a cylinder and place it on one of the circles. Place the other circle on the cylinder

With this, we now have our cylinder.

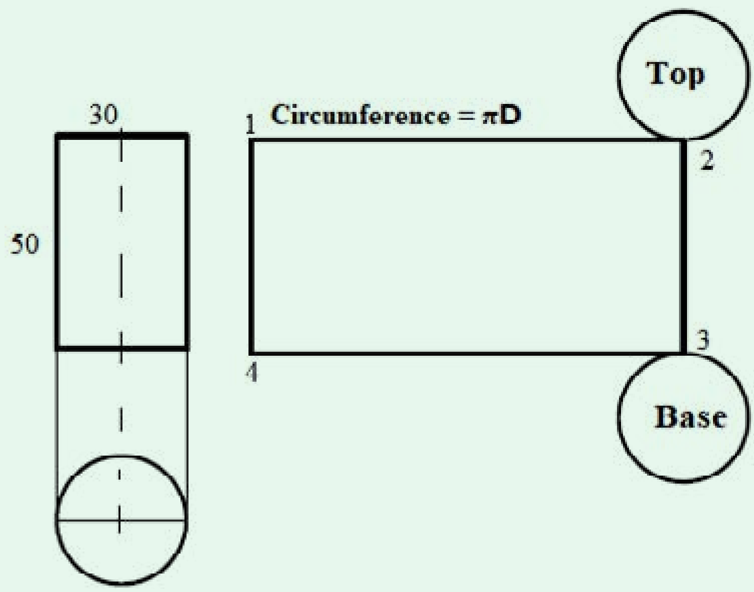


Fig. 3.23: A developed cylinder

UNDERSTANDING THE DESIGN PROCESS

Let us now elaborate on the design process used by design engineers and manufacturers for new and improved product designs.

The Design Process

Engineers follow a process to make new products to address the needs of society. The process begins with identifying a problem. Then engineers imagine, plan, create, and evaluate a product that addresses the problem. The design process is a systematic decision-making process to conceive an idea (solution or concept) and create feasible solutions to solve societal problems and needs. Figure 3.24 illustrates the 8-step general design process used for generating an idea and developing it into a prototype.

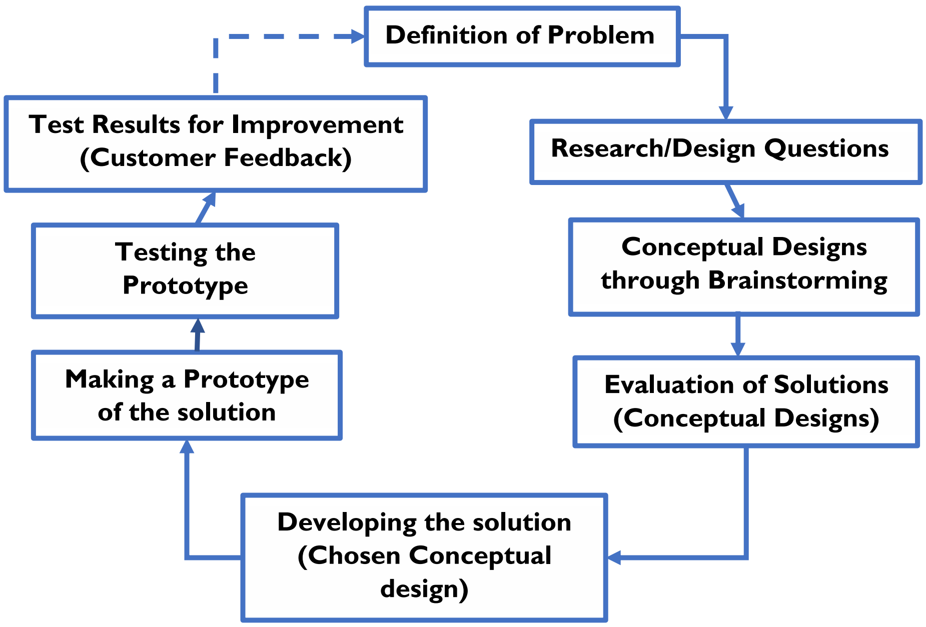


Fig. 3.24: The design process

Although the process is systematic, usually one is required to go back and examine some rejected ideas and use them directly or indirectly along the various stages of the design process. The systematic stages involved in the product design process include the following:

Step 1: Definition of the problem

The design process begins with identifying and defining a problem that needs a solution. This step should give a short description of the problem to include the product design requirements as well as factors such as economic (cost, social and legal) considerations. This basic information that is necessary to set the boundary or guidelines for the designer to solve the problem is called also called *design brief*. The design brief or market brief is a statement of need that describes the perceived need to update an existing product resulting from customers feedback or the need to provide a solution to a newly identified problem.

Purpose: To recognise a specific issue that needs to be addressed.
Ask yourself: What is the challenge? What needs to be improved? What is the need?

Example of 'Definition of the problem' or Design Brief:

The existing hoe is to be modified for farmers to be used for weeding in backyard farms and other small-scale farms to reduce waist pains and the stress in the arms of farmers. Design and manufacture an affordable hoe to be used in rainy and sunny weather conditions for farmers using locally available materials. The Existing weeding hoe used by farmers is shown in Figure 3.25.

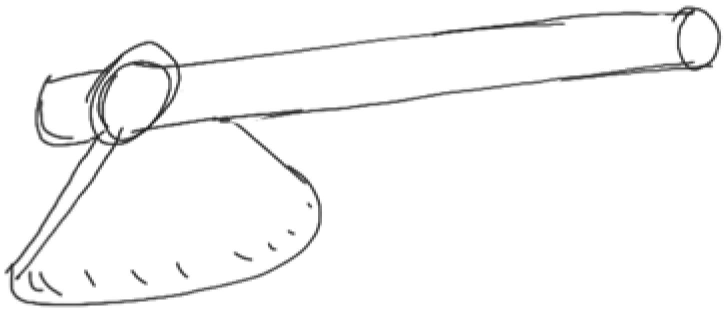


Fig. 3.25: Existing weeding Hoe Design

Step 2: Research/design questions to understand the problem

This involves understanding the problem that needs to be addressed through questioning. It is mostly done through market research and gathering input from stakeholders and expected customers or end-users. These questions also help to straighten the boundaries or guidelines for the brainstorming sessions. For example, if the existing hoe is to be modified for farmers to be used for weeding in their backyard farms or small scale farms to reduce waist pains and the stress in the arms, there are a number of questions that would be necessary to guide the possible solutions.

Purpose: To gather information
Ask yourself: What questions do I have? What observations can I make?
Do solutions to the problem exist? How can they be improved?
What materials are available? What could limit my solution?

Based on the design brief in step one, the following design questions are relevant:

- What should be the maximum mass of the hoe?
- What is the maximum height of the hoe handle that would be suitable for the average sized farmer?
- What kinds of materials are suitable for the hoe based on the weather conditions?
- What should be the width of the hoe blade?
- What manufacturing method would be used to produce the hoe blade and handle?

- What lifespan of the hoe is required?
- Would the farmers accept the modified design?

Step 3: Brainstorming potential solutions (conceptual designs)

This involves the generation of ideas through brainstorming and exploring various concepts with sketches, design ideas, and different approaches to solving the problem. Brainstorming is a group-based activity for the generation of multiple ideas and concepts to fulfil a given design requirement.

It is expected that aspects of a few of the concepts generated should be combined to form a solution to the design need. The following rules are helpful for brain-storming sessions.

- It should be a group activity undertaken by members with strengths from different subject areas.
- There should be no more than five people present in order to preserve an effective group dynamic.
- Flip charts, marker pens, pencils and paper should be uses to facilitate communication and recording of ideas.
- The design brief and design questions should be clearly stated at the start of the session.
- You are encouraged to add to the content presented by others in a respectful manner. You are also encouraged to tolerate others' views.

At the end of the brainstorming sessions, several conceptual designs (say three conceptual sketches) should be generated for subsequent evaluation and elimination to obtain the best design.

Purpose: To think of several ways to solve the problem
Ask yourself: What are the different ways of solving the problem?
What materials are needed? Can I use the available materials to solve the problem?
Can I use existing technology to solve the problem?

Figures 3.25 to 3.28 shows three conceptual designs or sketches for a new weeding hoe design that could be used by farmers.

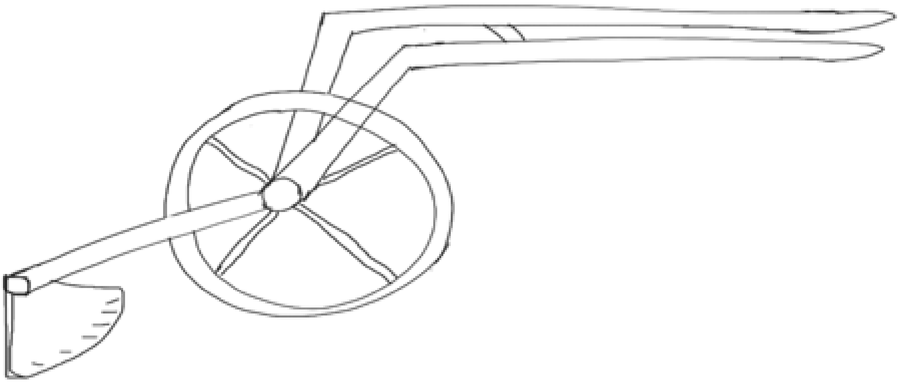


Fig. 3.26: Conceptual sketch 1

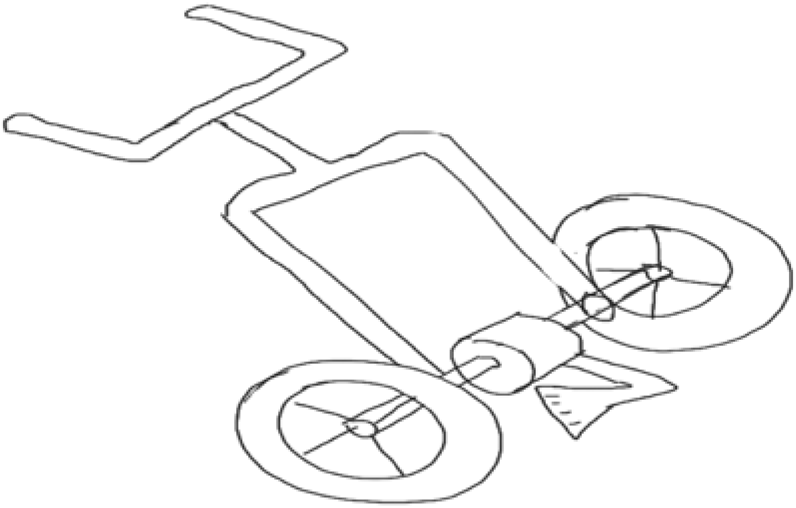


Fig. 3.27: Conceptual sketch 2

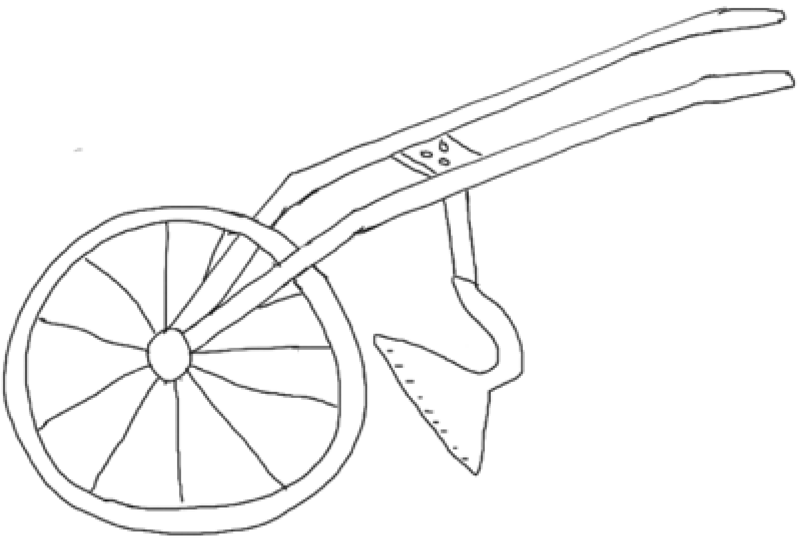


Fig. 3.28: Conceptual sketch 3

Step 4: Deciding on a solution using an evaluation criterion essential to the solution

This involves assessing and evaluating the generated concepts based on criteria such as functionality or performance, ease of manufacture, safety, and cost, and selecting the best design concept that aligns with project objectives and constraints. Usually, an evaluation matrix consisting of conceptual designs, criteria and scores are tabulated to obtain the best design.

Purpose: To decide which solution best solves the problem.
Ask yourself: What are the strengths and weaknesses of each solution?
Which solution is the most useful? Which solution is the least complicated?
How will I develop my solution?

Example of the evaluation matrix which could be used to evaluate the hoe design is given in Table 3.4.

Table 3.4: Evaluation Matrix

Criteria	Scores for Conceptual Designs / Sketches		
	Design 1	**Design 2**	**Design 3**
Performance	*4*	*3*	*5*
Durability	*3*	*5*	*4*
Cost	*4*	*3*	*4*
Ease of manufacture	*4*	*2*	*4*
Total Scores	*15/20=75%*	*13/20=65%*	*17/20=85%*

NB: The score for each criterion as at depends on the designer. For instance, a value for (say cost) could range from 5 (lowest cost) to 1 (highest cost). From the Evaluation Conceptual Design 3 emerges as the best design.

Step 5: Developing the solution

Once the best solution (chosen design) is obtained, it has to be developed to a form that could be manufactured. The initial analysis on the chosen design has to do with quantifying the forces, torques, moments and other loads that may directly or indirectly affect the component. Then a material of the right strength capable of withstanding or resisting all the expected loadings (forces, moments and torques) is selected for chosen design. This implies that some basic calculations have to be done to arrive at the right dimensions.

For the design of a modified hoe example, the following calculations can be done:

- The moment of force in the arm that could be used to dig out the soil (for the bed) should be equal or greater than the moment of force needed to deform the soil.
- Stress induced in the blade of the hoe during digging should be less that the strength of the blade material.

Purpose: To improve on the chosen design to ensure it can withstand expected forces
Ask yourself: What materials can resist the forces?
What thicknesses or sizes can help the product to function as expected?
What special characteristics, flexibility in dimensions or allowances should be permitted?

Once the dimensions are obtained, the 3D computer-aided design (CAD) models and engineering drawings that depict the product's geometry and components are generated. Additionally, other specifications for tolerances may be added to ensure standardisation and interchangeability of the designed parts.

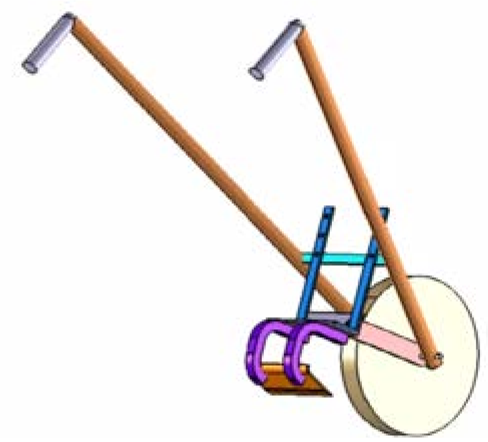


Fig. 3.29: 3D Model of the Conceptual Design 3

Step 6: Making a prototype of the solution

At this stage the detailed drawings or the engineering drawings are used as a guide to form the parts that cannot be found directly from the market. Those parts that could be found from the market are purchased or sometimes could be formed at the workshop. This stage involves building physical prototypes or models to validate the design and test its functionality. At this point, materials for the product are chosen based on their properties such as strength, conductivity, and toughness. Additionally, the manufacturing processes required for each component or part and the joining methods between components are spelt out. Other factors such as tolerances, precision, efficiency and scalability are considered. The bottom line here is that the first model of the design is manufactured using the formed or machined parts or is fabricated using standard parts form the market.

Purpose: To plan a design, gather materials, and build a model of your solution
Ask yourself: What materials do I need? How do I build a functional model?
What are the special characteristics, or specifications, of my model?

Step 7: Testing the prototype

This stage involves conducting some tests and experimentation on the manufactured product (prototype) to verify that its performance is acceptable by the designer based on the products purpose. The prototype should be helpful and user friendly to the end-users. It should be environmentally friendly, socially acceptable and legally compliant.

Purpose: To see how well your design worked
Ask yourself: Did it work? Did it accomplish what I wanted it to do?
Did anything else happen during my test that I didn't expect?

A completed device can be tested by the following means:

- Dropping to ascertain its impact resistance and durability.
- Shaking it to confirm how rigid the body and joints are.
- Using it to verify if it can serve the purpose for which it was designed.

Step 8: Improving the design based on test results or feedback from customers

The feedback from the test results or from the customer or end user is usually in the form of a challenge or a problem which needs to be addressed. This would demand that the design process begins again for improvement design of that product. It then takes us back to step one of the design process. Hence, the design process is cyclical in nature.

Purpose: To consider how to improve your design based on test results.
Ask yourself: Did my design produce the best expected results?
How could I make it better? Is it practical? Are the materials cheap and easy to find? Does my solution create new problems, or the need for another new product?
Will others be able to use it equally as well?

Activity 3.10

Make a search from the internet on design brief, brainstorming, prototype, conceptual design and design calculations used in the design process or watch the following videos and perform the task that follows.

- https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process
- https://www.youtube.com/watch?v=oBqGoXCBHtk
- https://www.youtube.com/watch?v=NeVxOAceij0

Use flashcards to show any three of the following terms and their corresponding meanings.

1. Design brief
2. Brainstorming

3. Prototype
4. Conceptual design and
5. Design calculations

An example is given below.

Design Process	→	A systematic decision-making process to conceive an idea and create a feasible solution

Activity 3.11

A product or a machine (with a pull-down mechanism) is to be designed to enable the physically challenged access (reach and use) a microwave using the pull down and retraction mechanism. State and explain the major task involved in the design process for such a machine. Include one conceptual design. Use the template below to present your design ideas.

Step	Design Stage	Explanation of Sub-activities
1		
2		
3		
4		
5		

Activity 3.12

Your community is facing a serious sanitation problem. There are issues with solid waste disposal, sewage disposal, littering at the market area and poor drainage system. As a design and manufacturing team, propose one solution to mitigate the problem in your community and communicate the same to the Metro/Municipal/District Assembly. Your solution should include the design brief, research questions, brainstorming/conceptual sketches, evaluation criteria/matrix, developing the best solution through design analysis /calculations and detailed drawing with dimensions as well as fabrication/manufacturing methods for the proposed solution or machine. Also, use wood, cardboard, polystyrene foam and other less expensive materials to build your prototype and test. Use the template below to write your report.

<table>
<tr><th>Step</th><th>Design Stage</th><th>Explanation of Sub-activities</th></tr>
<tr><td>1</td><td>Definition of Problem (design brief)</td><td></td></tr>
<tr><td>2</td><td>Research/Design Questions</td><td></td></tr>
<tr><td>3</td><td>Conceptual Designs through Brainstorming</td><td>Sketch of Design 1:
Sketch of Design 2:
Sketch of Design 3:</td></tr>
<tr><td>4</td><td>Evaluation of Solutions (Conceptual Designs)</td><td>
<table>
<tr><th rowspan="2">Criteria</th><th colspan="3">Scores for Conceptual Designs</th></tr>
<tr><th>Design 1</th><th>Design 2</th><th>Design 3</th></tr>
<tr><td>Performance</td><td></td><td></td><td></td></tr>
<tr><td>Durability</td><td></td><td></td><td></td></tr>
<tr><td>Cost</td><td></td><td></td><td></td></tr>
<tr><td>Ease of manufacture</td><td></td><td></td><td></td></tr>
<tr><td>Total Scores</td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>5</td><td>Developing the solution (Chosen Conceptual design)</td><td>Basic calculations (if any)
3D CAD Model /Engineering Drawings</td></tr>
<tr><td>6</td><td>Making a Prototype of the solution</td><td>Joining methods (if any)
Fabrication/manufacturing processes</td></tr>
<tr><td>7</td><td>Testing the Prototype</td><td></td></tr>
<tr><td>8</td><td>Test Results for Improvement (Customer Feedback)</td><td></td></tr>
</table>

Activity 3.13

With your team from Activity 3.12, create a PowerPoint presentation of solutions to the sanitation problem in activity 3.11. Present your findings to the class for feedback.

IMPORTANCE OF FREEHAND SKETCHING AND VISUALISATION OF OBJECTS

A designer records his ideas initially in the form of freehand sketches which are later converted into drawings. Ideas and objects can be described in words, but the description is made more expressive with the aid of sketches. Freehand sketching allows for spontaneous expression of ideas and creativity. Both freehand sketches and visualisations work together to help designers develop concepts that are both functional and aesthetically pleasing.

Manufacturers, engineers, artists, and designers can quickly capture their thoughts without being constrained by tools, nevertheless, paper/sheet, pencil, and eraser as tools mostly used for freehand sketching. The use of instruments such as straight edges, templates, T-square, set squares, pairs of compasses, and French curves are not allowed during freehand sketching. They slow down the process and defeat the purpose of fast communication of ideas.

Steps for Making Freehand Sketches

1. Visualise and plan the sketch: Think about the size of the paper and scale to use, orientation of the object, minimum detail to communicate the idea, and type of sketch to use (oblique, isometric, orthographic).
2. Outline the sketch: Use light lines to provide an outline for the sketch.
3. Show major edges and boundaries of the sketch.
4. Add more details.
5. Shape the sketches: This is done by adding appropriate details and darkening object lines. The steps above are illustrated in Fig. 3.30.

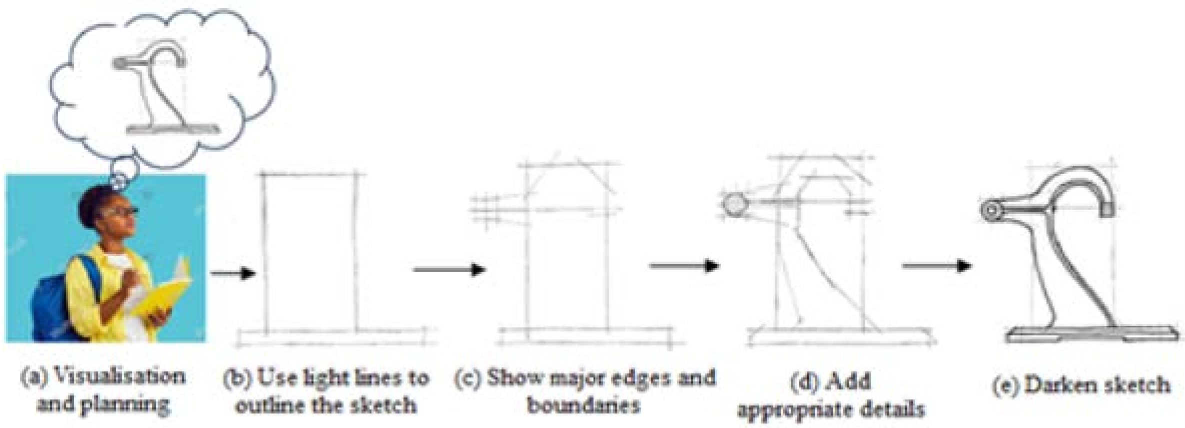


Fig. 3.30: Steps for making freehand sketch of an idea (Teachers Manual)

Rules for Making Freehand Sketches

A. Drawing lines

a. Locate a start point.
b. Locate an end point.
c. Put pencil on start dot, look at the end dot and smoothly move pencil toward the end dot as shown in Fig. 3.31.

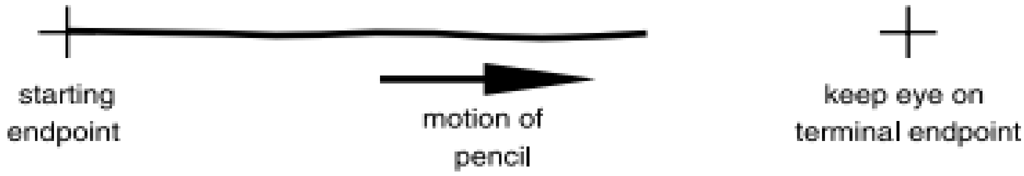


Fig. 3.31: Sketching a line

B. Drawing circles (arcs)

a. Draw light horizontal and vertical lines that intersect at the centre.
b. Lightly mark the radius on the lines.
c. Connect the radius marks with arcs to complete the circle as shown in Fig. 3.32.

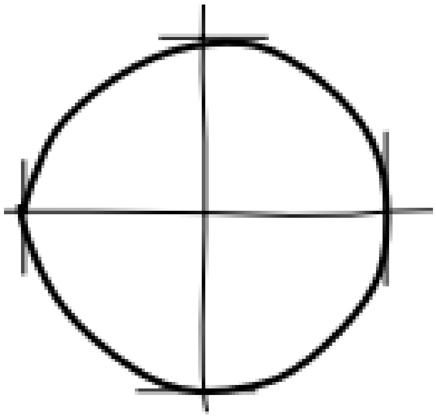


Fig. 3.32: Sketching a circle

C. Making an Oblique Sketch

a. Draw the horizontal and vertical construction lines which outline the basic shape of the main face.
b. Sketch in the face of the part.
c. Sketch receding construction lines at 30 or 45 degrees.
d. Sketch in and darken the lines outlining the part as shown in Fig. 3.33.

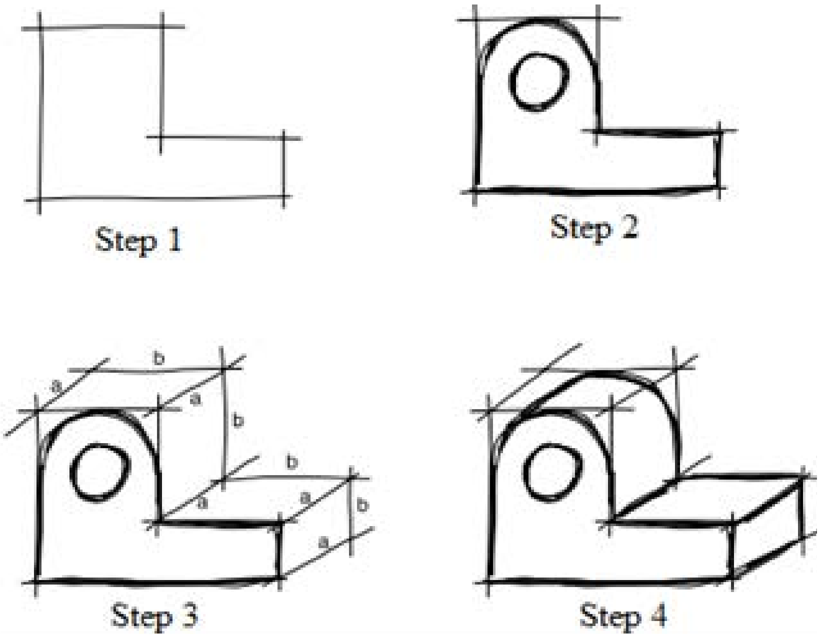


Fig. 3.33: Making an oblique sketch (Teachers Manual)

D. Making an Isometric Sketch

a. Construct a horizontal line, two lines at 30 degrees above the horizontal and a vertical line through their intersection. This defines the isometric axes used to draw the sketch.
b. Sketch in a box to "block-in" the front face and the other faces follow.
c. Sketch the outline of the front face in its "block" and the other faces follow. Work parallel to the isometric axes as shown in Fig. 3.34.

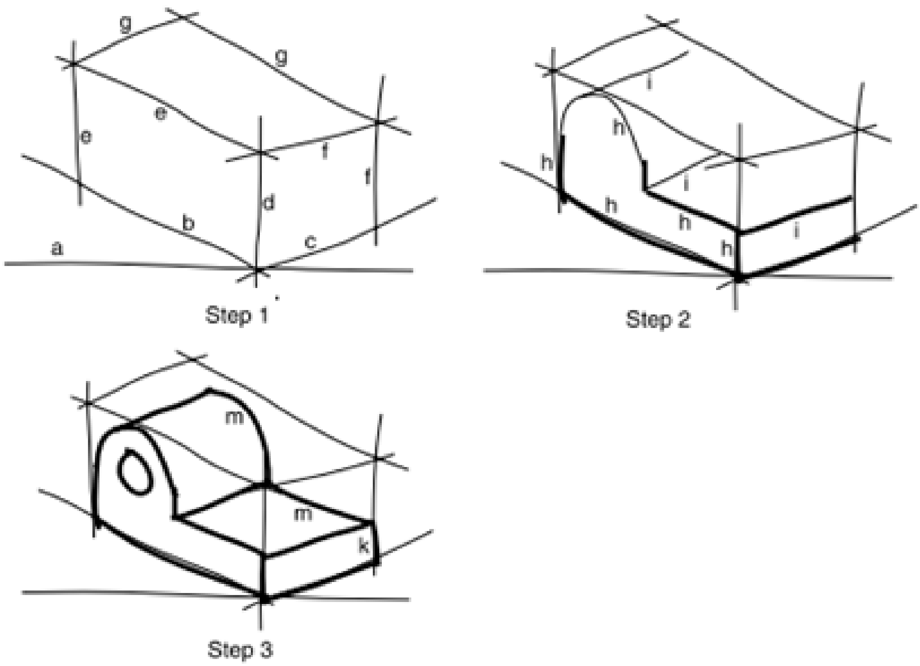


Fig. 3.34: Making and isometric sketch (Teachers Manual)

Activity 3.14

Watch the following videos and carry out freehand sketching and visualisation of objects using the links provided combined with guidance from your teacher.

- https://www.youtube.com/watch?v=ceK1tEGZals
- https://www.youtube.com/watch?v=Ess0dmJB2lo

Activity 3.15

1. Follow the steps below to make a freehand sketch of a circle.

Note: Rest your hand lightly on the paper as beginner. If the circle isn't perfect on the first try, don't worry. You can adjust the shape by erasing and refining until you're satisfied with the result

Steps:

a. Draw light horizontal and vertical lines that intersect at the centre.
b. Gently mark the radius of the on the lines.
c. Connect the radius marks with arcs to complete the circle as shown.

2. Follow the steps below to make a freehand sketch of a triangle.

Steps:

a. Draw light horizontal mark the base of the triangle and leter it AB.
b. Produce a perpendicular lines to the base line.
c. Gently mark the height of the triangle on the perpendicular line and letter it C.
d. Gently join the points to complete the triangle

3. Follow the steps below to make a freehand sketch of a square.

Steps:

a. Draw a horizontal line, mark the lenght of the rectangle and leter it AB.
b. Produce a perpendicular lines to the base line at point A and B.
c. Gently mark the breadth of the rectangle on the two perpendicular lines and letter them C and D.
d. Gently join the points the to complete the rectangle.

Activity 3.16

1. Using guidance from your teacher and information from the following video follow the steps below to sketch a chair on your own in freehand.

   https://www.youtube.com/watch?app=desktop&v=vkECt-gauNM

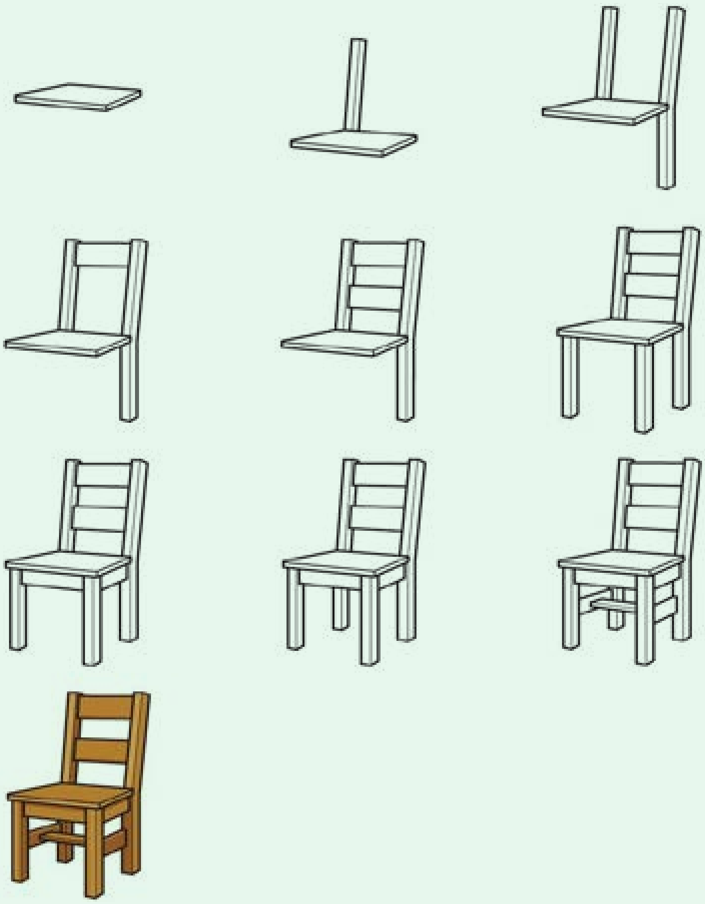


Fig. 3.35a: Steps in sketching a chair

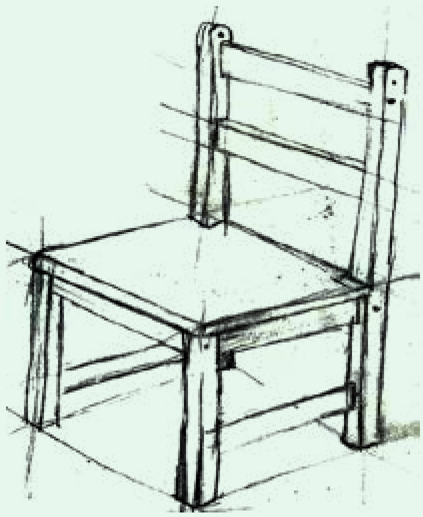


Fig. 3.35b: Completed chair.

2. Using guidance from your teacher and information from the following tutorial, follow the steps below to sketch a table on your own in freehand.

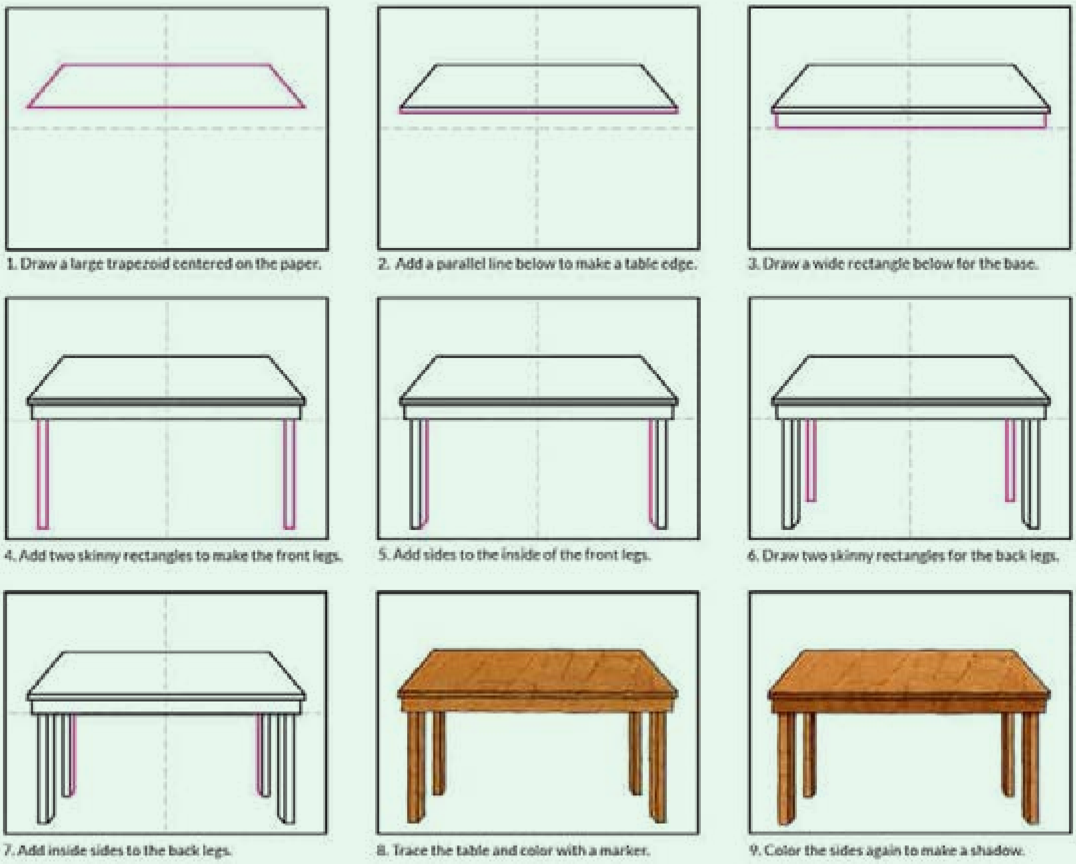


Fig. 3.36a: Steps in sketching a table

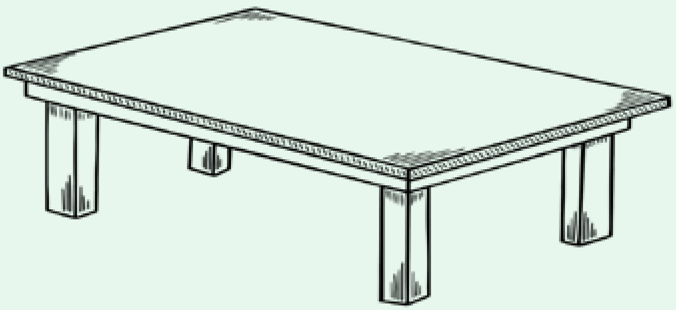


Fig. 3.36b: Completed table

Activity 3.17

Now, think about any product you may want to design to help your community, (such as something to solve sanitation problems), and sketch this product using freehand.

Review Questions

REVIEW QUESTIONS 3.1

1. Using drawing instruments, draw the border line and title block for a product to be designed.
2. Compare and contrast the use of a French curve and a pair of compass in drawing a curve and discuss the conditions within which one would be preferred over the other?
3. You are required to design a product that has both straight and curved shapes. Which drawing instruments will you use to draw each shape and why?
4. Using the drawing board and other instruments, draw a circle of diameter 80mm and a rectangle of length 70mm and height 45mm.
5. With the help of your drawing instruments, draw a circle of diameter 60mm and divide it into twelve (12) equal parts.

REVIEW QUESTIONS 3.2

1. Explain the method of surface development used in the manufacturing of tin tomato cans.
2. Fabrication of coal pots involves cutting patterns of shapes on a sheet metal, explain the relation of coal pot fabrication to surface development.
3. Explain the relationship between the dimensions of an object and its corresponding developed surface?
4. Produce the surface development of a household funnel and explain the methods used.
5. Explain how manufacturing of a complex shape can be achieved in the surface development of the part.

REVIEW QUESTIONS 3.3

1. Describe three important criteria that should be used to evaluate a charcoal stove design that aims at reducing heat loss from the heating chamber to the surrounding environment.
2. Explain why establishing design criteria is important when proposing solutions to community problems.
3. Identify one critical problem in your community and propose a solution using the design process. Use the design template of **Activity 3.12** to develop a solution to the problem in the community.
4. Several design proposals have been put forward by different bidders to address a water shortage and pollution problem in your community. Discuss how

the design process and evaluation criteria will aid in arriving at an effective solution the water shortage and pollution problem in your community.

5. Feasibility studies and Designs are to be undertaken for a new fruit juice factory to pave the way for its implementation at a named location. As a project leader of the feasibility team, explain to your team why you think the design process would be effective for this project.

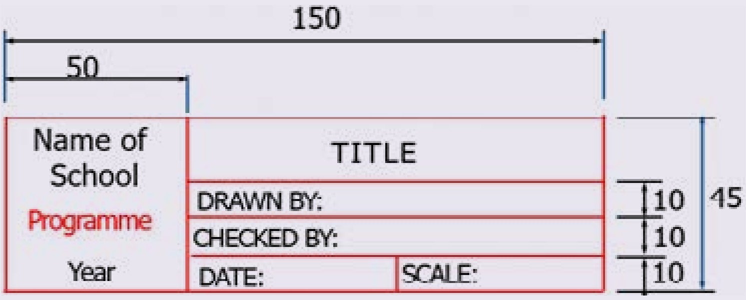
REVIEW QUESTIONS 3.4

1. Create three different freehand sketches of a design concept for a desk or a sitting unit.
2. Evaluate the impact of freehand sketching on improving the ability to effectively develop and communicate design concepts
3. Assess the advantages and disadvantages of using freehand sketching compared with the use of drawing instruments during the design process.
4. Explain why freehand sketching is often used in the initial stages of product design.
5. Explain how visualisation aids engineers and designers to identify potential problems of a design.

Answers to Review Questions

ANSWERS TO REVIEW QUESTIONS 3.1

1.



2. Both French curve and a pair of compass are very important instruments in manufacturing design. The choice of a French curve and a pair of compasses depends largely on the type of curve needed (regular or irregular), the level of precision required, and technical demands of the drawing or design project.

   French curves are flexible templates with various curves that allow designers to trace complex curves such as parabolic arcs or ellipses. They are more preferred when drawing irregular or complex curves that cannot be generated with a pair of compasses

   Pairs of compasses are used to draw precise, symmetrical arcs and circles of various diameters. They adhere strictly to predefined radii. Pairs of compasses are preferred when drawing regular geometric shapes like circles and arcs to specific radii. They cannot create complex, irregular curves like that of a French curve.

3. To be able to design/draw objects that have both straight and curved shapes such as cylinders, cones, rectangles, and squares, the following drawing instruments would be required.

   i. Ruler: Is used for drawing straight lines with precision. It ensures that lines are perfectly straight and consistent in length.

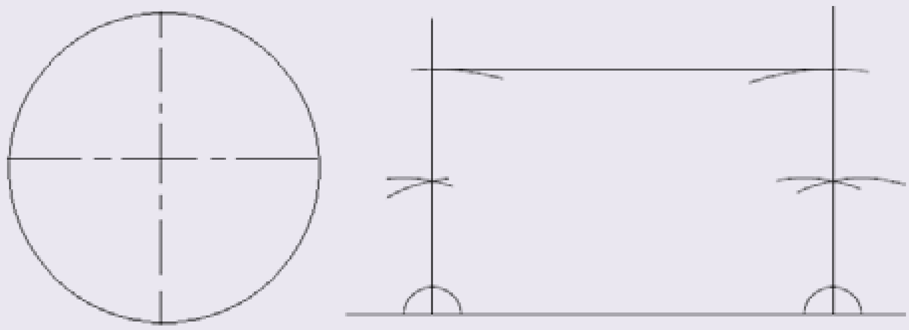
   ii. T-square: A T-square is used in conjunction with a ruler to draw horizontal lines. It helps to draw accurate and parallel lines.

   iii. Set Square: Set squares, particularly the 45° and $30^0/60°$ set squares, are used to draw accurate angles. They are used in conjunction with the Tee square to draw vertical or perpendicular lines.

   iv. A pair of compasses: Is used for drawing precise circles and arcs of varying radii. It allows for accurate measurements.

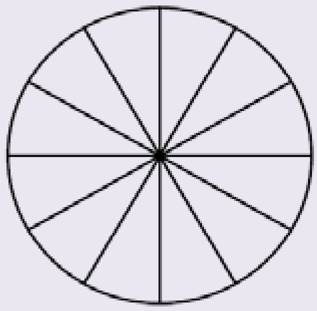
   v. French curve: A French curve is used to draw smooth, freehand-like curves that are irregular or complex in shape. It provides flexibility in creating organic and artistic curves that are difficult to be drawn with a pair of compasses.

6.



A circle of diameter 80mm A rectangle of sides 70mm and 45mm

7.



A circle of diameter 60mm divided into twelve (12) equal parts using set squares

ANSWERS TO REVIEW QUESTIONS 3.2

1. Tin tomato cans are made of cylindrical cans. The surface development is made by the parallel line method where the surface is unrolled from the can and with both a top and bottom base circles.
2. Coalpots are made from sheet metal, the patterns of coalpots are drawn on the sheet metal using the parallel line and triangulation method at different areas of the coalpot. The patterns are then cut and welded together to form a coalpot.
3. In manufacturing, the area and dimensions of a 3D object it's needed to know the quantity of material needed for a product. Surface development presents a 2D view of the object thereby making it easy for the manufacturer and designer to know the material quantity and dimensions that can be moulded to get the object.
4. Most household funnels are made up of two parts, a conical and a cylindrical part, to produce the surface development, create the development of the cylindrical part and the conical part.
5. Manufacturing of complex shapes are made possible using triangulation surface development method. Multiple triangles are drawn on the surface to create an accurate development.

ANSWERS TO REVIEW QUESTIONS 3.3

1.

i. Insulation Quality: The type and quality of insulation material used around the heating chamber. Heat-resistant materials that minimise thermal conductivity are ideal. The thickness of the insulation layer. Thicker insulation typically reduces heat loss more effectively.

ii. Good Stove Design and Construction: The stove should have minimal gaps and leaks where heat could escape. Proper sealing of joints and openings is crucial. Stoves with double walls can trap air between the layers, acting as an additional insulator. Efficient control of airflow into and out of the stove to maintain combustion efficiency and minimise unnecessary heat loss.

iii. Material of the Stove: Materials with low thermal conductivity for the outer layer of the stove to prevent heat transfer to the environment. The material should withstand high temperatures without degrading or losing insulating properties over time.

iv. Combustion Efficiency: Efficient combustion of charcoal to ensure maximum heat is produced with minimal unburned fuel. Design features that retain and reflect heat back into the heating chamber, such as reflective linings or coatings.

v. Environmental Impact: The level of emissions produced by the stove, including smoke and particulate matter, as these can indicate inefficiencies in combustion and heat loss. The amount of charcoal required to achieve the desired cooking results, with more efficient stoves using less fuel.

2.

The following are some of the reasons for establishing design criteria when solving a design problem:

i. Design criteria provide clear, measurable goals for what the solution should achieve, ensuring that efforts are directed towards specific, desired outcomes.

ii. Criteria ensure that solutions are tailored to the specific needs and conditions of the community, increasing the likelihood of acceptance and success.

iii. Design criteria guide the design process towards enhancing the performance of the solution, ensuring that it meets the desired standards.

iv. Design criteria provide a basis for measuring the performance of the solution, allowing for objective evaluation and continuous improvement.

v. Criteria ensure that solutions are not only effective in the short term but also sustainable and resilient in the long run. It ensures that the solution to the problem is environmentally and socially sustainable a well as contribute positively to the community's future.

3. Refer to the design template for Activity 3.12.

4. When several design proposals are presented the design process and clear evaluation criteria are crucial for selecting the most effective solution.

   The Design Process

   i. Define the Problem: Ensures all stakeholders have a common understanding of the specific aspects of the water shortage and pollution problem. Helps in identifying the key issues that need addressing, such as contamination sources, affected areas, and water usage patterns. Research and gather information to provides a solid knowledge base about the problem, including water quality data, community needs, and existing solutions.

   ii. Ensures solutions are based on the specific conditions and constraints of the community, such as geographical, environmental, and socio-economic factors.

   iii. Brainstorm and Generate Ideas: Innovation: Encourages creative thinking and the generation of diverse ideas, leading to a broader range of potential solutions.

   iv. Define Design Evaluation Criteria and Evaluate designs: Establishes clear, measurable goals that each proposal must meet, such as effectiveness, cost, sustainability, scalability, and ease of use. Helps in prioritising the most critical aspects of the problem, ensuring that solutions address the most pressing needs first

   v. Develop the Solution: Develop the design by going through some calculations, analysis and finalising the drawings.

   vi. Build Prototype

   vii. Test Prototype

   viii. Evaluate the test results and Community Feedback: Involves the community in the testing phase, ensuring that solutions are user-friendly and meet the community's needs.

   Some of the Evaluation design Criteria mentioned in (iii) above includes:

   - **Effectiveness**: The solution should significantly reduce pollution levels and provide clean water. It should increase the availability of water to meet the community's needs.
   - **Affordability**: The solution should provide maximum benefits relative to its cost. It should be within the financial capabilities of the community or attract sufficient funding.
   - **Sustainability**: The solution should have a minimal negative impact on the environment. It should be sustainable in the long term, considering factors like maintenance and resource availability.
   - **Scalability**: The solution should be adaptable to changes in population and water demand. It should be replicable in other similar communities facing the same issues.

- **Ease of Use**: The solution should be easy for community members to use and maintain. It should require minimal training for effective use.
- **Community/Social Acceptance**: The solution should be culturally acceptable to the community. It should involve and gain the support of the community members.

By following through the design process and evaluating proposals against these criteria, decision-makers can objectively assess which proposal offers the most effective, sustainable, and acceptable solution to the water shortage and pollution problem in the community.

5. As the project leader of the feasibility team for the new fruit juice factory, it's essential to emphasise the importance and effectiveness of the design process in ensuring the project's success. The following are some importance of using design process:

   i. Problem Understanding. The design process begins with a detailed understanding of the project requirements, including production capacity, quality standards, and market demand. It helps identify potential risks and challenges early on, such as supply chain issues, regulatory compliance, and environmental impacts.

   ii. Research and Data Collection. Conducting market research ensures that there is a demand for the product and identifies the target consumer base, competition, and pricing strategies. Gathering data about the proposed location, including accessibility, local infrastructure, labour availability, and environmental factors.

   iii. Clear Design Criteria. Establishing clear, measurable criteria for the factory design, such as production efficiency, cost-effectiveness, sustainability, and compliance with health and safety standards. Ensuring that all design efforts are aligned with the overall project goals and community needs.

   iv. Idea Generation and Brainstorming. Encouraging team members to contribute different ideas and approaches to the factory design, fostering creativity and innovation. Considering a wide range of factors, including layout, technology, processes, and workflow optimisations.

   v. Prototype Development. Creating prototypes or models of key components of the factory, such as production lines, to test their feasibility and performance. Using simulations to analyse the efficiency, productivity, and potential bottlenecks in the manufacturing process.

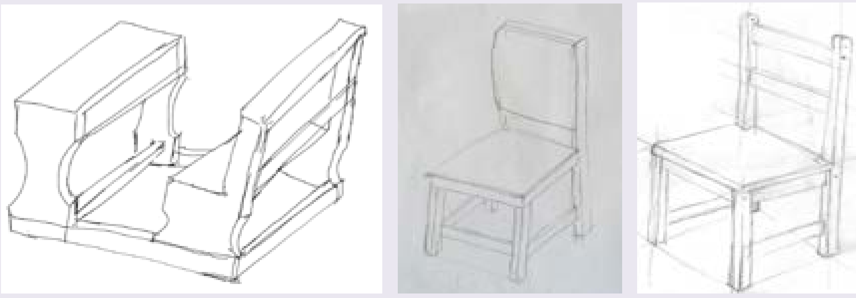
   vi. Testing and Evaluation. Implementing pilot projects or small-scale versions of the production process to gather data and evaluate performance. Collecting feedback from stakeholders, including potential employees, suppliers, and regulatory bodies, to make informed adjustments.

   vii. Environmental and Social Responsibility. Ensuring that the factory design incorporates sustainable practices and complies with environmental and social responsibility standards.

By adhering to the design process, we ensure a thorough, well-informed, and strategic approach to the development of the new fruit juice manufacturing factory. This process not only enhances the likelihood of project success but also ensures that the factory will be efficient, sustainable, and capable of meeting both current and future demands.

ANSWERS TO REVIEW QUESTIONS 3.4

1.



2. Freehand sketching allows for spontaneous expression of ideas and creativity. It helps designers to develop concepts that are both functional and aesthetically pleasing.

3.

Advantages

i. Sketching by hand is generally faster than using drawing instruments.

ii. It encourages creativity and quick iteration.

iii. Only basic equipment is needed, making it accessible anywhere and anytime.

Disadvantages

i. Lacks the precision required for detailed technical drawings.

ii. Making changes to a design made in freehand sketch can distort the beauty of the design and may require starting over.

iii. Enlarging or reducing freehand sketches can distort proportions and dimensions.

iv. Since it is often not drawn to scale it cannot be presented for competitive bidding.

4. Freehand sketching allows for fast communication of ideas and creativity without any difficulty. It allows designers to communicate their vision more easily, showing basic forms, proportions, and spatial relationships without the distraction of technical details.

5. Visualisation involves creating visual representations of ideas and concepts to help designers understand how they will look and function in the real world. Visualisation can take many forms, including sketches, diagrams, models, and prototypes. visualisation help designers develop concepts that are both functional and aesthetically pleasing.

Extended Reading

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