



GANDHI SCHOOL OF ENGINEERING

Brahmapur, Odisha

Laboratory Manual

Engineering Graphics and Design Laboratory

Complete Laboratory Manual

B.Tech 1st Year · Semester 1 · Circuit Branch

Academic Year 2026-27



About this lab manual

This manual covers the **Engineering Graphics and Design Laboratory** (0-0-2) for first-year B.Tech students. The experiments combine manual drawing principles (BIS conventions as per SP 46 : 2003) with computer-aided drafting in **AutoCAD** (any recent version, 2018 or later; the free AutoCAD student licence can be used at home).

Each experiment gives:

- **Aim, requirements and theory** with a neat figure of the finished drawing.
- **Step-by-step AutoCAD procedure** with the exact commands to type.
- **Precautions, result and viva-voce questions with answers.**

No.	Experiment	Page topic
1	Drawing instruments, sheet layout, lines, lettering and dimensioning	BIS conventions
2	Introduction to AutoCAD: interface, drawing and modify commands	CAD basics
3	Scales: plain and diagonal scales	Scales
4	Engineering curves: ellipse, cycloid, involute	Curves
5	Projection of points and straight lines	Orthographic projection
6	Projection of planes	Orthographic projection
7	Projection of solids	Orthographic projection
8	Sections of solids and true shape of section	Sections
9	Development of lateral surfaces of solids	Development
10	Isometric scale and isometric view	Pictorial drawing
11	Orthographic views from a pictorial view (first-angle)	Conversion
12	Building drawing: plan of a room and mini project	Applications of CAD

General instructions for the laboratory

- Bring the lab manual, record notebook, drawing instruments (for sketching) and a pen drive to every class.
- Save your work every 10 minutes (Ctrl + S) with the file name **RollNo-ExpNo.dwg** in your own folder.
- Set **units to millimetres** (UNITS command) and draw every object at full size (1 : 1) in model space; scales are applied only while plotting.
- Use separate **layers** for outlines, centre lines, hidden lines, dimensions and text, with the line types and weights given in Experiment 1.



- Take a printout (plot) of each drawing on A4 or A3 with a title block, and get it signed by the teacher in the next class.
- Switch off the computer properly, do not install software, and keep the laboratory clean.

Standard drawing sheet and title block

Designation	Size (mm)	Use
A0	841 × 1189	Large assemblies, site plans
A1	594 × 841	Drawing-board practice sheets
A2	420 × 594	Detailed drawings
A3	297 × 420	Most lab printouts
A4	210 × 297	Record sheets, small parts

A border of 10 mm (20 mm on the filing side) is drawn on every sheet. The **title block** (185 × 65 mm as per SP 46) is placed at the bottom right corner and contains: name of the institution, title of the drawing, drawing number, scale, method of projection (symbol), name and roll number of the student, date, and signature of the teacher.

Symbol of projection: first-angle projection (used in India as per BIS) is indicated in the title block by the standard symbol: the front view of a truncated cone together with its side view (two concentric circles), arranged according to the first-angle convention.



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Engineering Graphics and Design Lab

Experiments 1-12 · AutoCAD procedures · Figures · Viva questions with answers

Experiment 1: Drawing Instruments, Lines, Lettering and Dimensioning

Aim

To study drawing instruments and the BIS conventions for lines, lettering and dimensioning, and to prepare a sheet showing the types of lines and a dimensioned plate.

Requirements

Drawing board (or mini-drafter), set squares (45° and 30°-60°), protractor, compass and divider, scales, pencils (H, HB, 2H), eraser, clips, A3/A4 sheets; AutoCAD for the computer version.

Theory

Drawing instruments:

- **Drawing board and mini-drafter:** the mini-drafter combines a protractor head with two perpendicular scales; it replaces the T-square and set squares.
- **Set squares:** draw lines at 30°, 45°, 60°, 90° and (in combination) 15° and 75°.
- **Compass and divider:** the compass draws circles and arcs; the divider transfers and divides lengths.
- **Pencils:** 2H for construction lines, H for outlines, HB for lettering.
- **French curves:** draw smooth non-circular curves through plotted points.

Types of lines (SP 46 : 2003 / IS 10714)

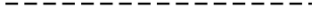
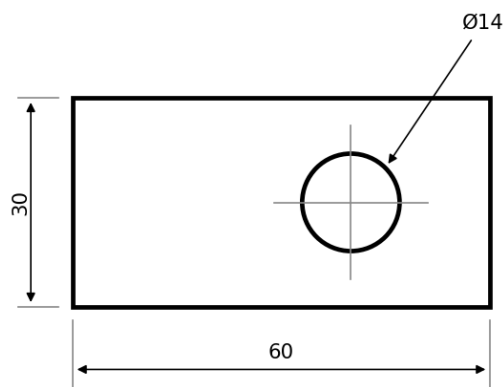
A		Continuous thick Visible outlines and edges
B		Continuous thin Dimension, extension, leader, hatching lines
C		Continuous thin freehand Limits of partial views, short break lines
E		Dashed thin Hidden outlines and edges
G		Chain thin (long dash-dot) Centre lines, lines of symmetry
H		Chain thin, thick at ends Cutting planes

Figure 1.1: Types of lines as per SP 46 : 2003.

Lettering: single-stroke capital letters, vertical or inclined at 75°. Recommended heights: 10 mm for the title, 5-7 mm for sub-titles, 3.5-5 mm for dimensions and notes. The ratio of height to width of letters is about 7 : 5 (Type B lettering, line thickness h/10).



Elements of a dimension:

- extension (projection) line
- dimension line with arrowheads
- dimension figure (above line)
- leader line for notes/diameters
- gap 1 mm, extension beyond 2–3 mm
- arrowhead length : width = 3 : 1

Figure 1.2: Elements of dimensioning: extension lines, dimension lines, arrowheads, figures and leaders.

Rules of dimensioning:

- Every dimension is given only once, in millimetres (unit not written); the dimension that is to be used should not have to be calculated.
- Dimensions are placed outside the view as far as possible, and the smaller dimensions inside the larger ones, so that extension lines do not cross dimension lines.
- **Aligned system:** figures are placed above the dimension line, readable from the bottom or the right side of the sheet. **Unidirectional system:** all figures are horizontal, readable from the bottom (the dimension line is broken for the figure).
- Diameters are shown with the symbol Ø, radii with R, squares with □; centre lines are not used as dimension lines.
- Dimensions are not given to hidden lines.

Procedure (in AutoCAD)

- Start AutoCAD, create a new drawing with the **acadiso.dwt** template (metric) and type **UNITS** → length type decimal, precision 0.00, insertion scale millimetres.
- Type **LIMITS** → 0,0 and 420,297 (A3), then **ZOOM** → **All**.
- Create layers with **LAYER** (LA): OUTLINE (continuous, 0.5 mm, white), THIN (continuous, 0.25 mm), HIDDEN (HIDDEN2, 0.25 mm), CENTER (CENTER2, 0.25 mm), DIM (0.25 mm, green), TEXT (0.25 mm). Load line types with **LINETYPE** → **Load** and set **LTSCALE** to 0.5-1.
- Draw the border with **RECTANG** (REC): first corner 20,10 and other corner 410,287. Draw the title block (185 × 65) at the bottom right.
- Draw each type of line on its layer; add the description with **MTEXT** (T) or **DTEXT** (DT) using a text style (**STYLE**: font ISOCPEUR or Arial, height 3.5).
- Draw the plate of Figure 1.2 with **LINE**, **CIRCLE** and the dimensions with **DIMLINEAR** (DLI), **DIMDIAMETER** (DDI) and **QLEADER** (LE). Set the dimension style with **DIMSTYLE** (D): text height 3.5, arrow size 3, extension beyond line 2, offset from origin 1.
- Save the file and plot it on A3 with **PLOT** (Ctrl + P), plot scale 1 : 1, monochrome.ctb plot style.



Precautions

- Keep outlines thick and dark, construction lines thin and light.
- Keep a uniform height for all lettering of one kind.
- Do not crowd dimensions; keep 8–10 mm between the outline and the first dimension line.

Result

The types of lines, lettering and a dimensioned plate were drawn according to BIS conventions.

Viva-voce questions

Q1. Which Indian standard gives the code of practice for engineering drawing?

SP 46 : 2003 (Bureau of Indian Standards), which follows ISO standards.

Q2. What line is used for hidden edges and for centre lines?

Hidden edges: dashed thin line (type E). Centre lines: long chain thin line (type G).

Q3. What is the difference between the aligned and unidirectional systems of dimensioning?

In the aligned system figures are aligned with the dimension lines and read from the bottom or right; in the unidirectional system all figures read from the bottom of the sheet.

Q4. What is the size of an A3 sheet?

297 × 420 mm (half of A2; each size is half the next larger one, with sides in the ratio 1 : $\sqrt{2}$).

Q5. What is the ratio of length to width of an arrowhead?

About 3 : 1.

Q6. Why is single-stroke lettering used?

It is quick to write, uniform and easily readable, and suits both manual and CAD drawings.

Experiment 2: Introduction to AutoCAD – Interface, Draw and Modify Commands

Aim

To become familiar with the AutoCAD user interface and to use the basic draw, modify, display and precision (object snap) commands to draw simple two-dimensional figures.

Requirements

Computer with AutoCAD 2018 or later, mouse, printer or plotter.

Theory

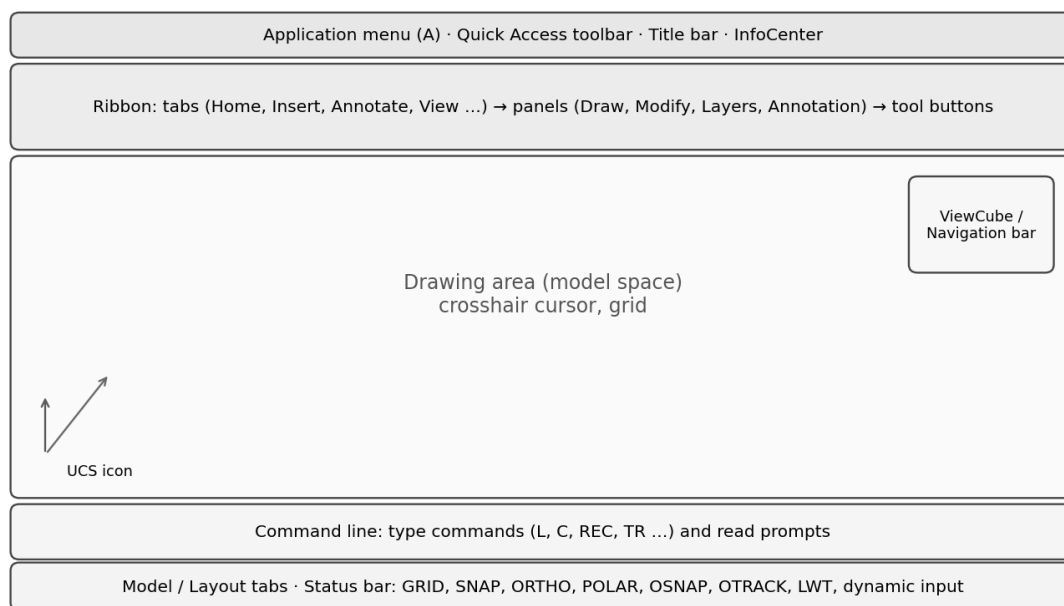


Figure 2.1: The AutoCAD user interface.

Computer-aided design (CAD) is the use of computers to create, modify, analyse and document designs. Advantages over manual drafting: higher accuracy, speed in editing and copying, easy storage and sharing, standard libraries of symbols, layers, automatic dimensioning, and direct use of drawings for manufacturing (CAM) and analysis.

Methods of entering coordinates:

Method	Format	Example	Meaning
Absolute Cartesian	x,y	50,30	Point 50 mm right and 30 mm up from the origin
Relative Cartesian	@dx,dy	@40,0	40 mm to the right of the last point
Relative polar	@distance<angle	@60<30	60 mm at 30° from the last point (angles anticlockwise from the +x axis)
Direct distance	move cursor, type distance	40 (with ORTHO on)	40 mm in the direction of the cursor

Important commands (with aliases):



Group	Commands
Draw	LINE (L), PLINE (PL), CIRCLE (C), ARC (A), RECTANG (REC), POLYGON (POL), ELLIPSE (EL), SPLINE (SPL), HATCH (H), POINT (PO)
Modify	ERASE (E), MOVE (M), COPY (CO), ROTATE (RO), SCALE (SC), MIRROR (MI), OFFSET (O), TRIM (TR), EXTEND (EX), FILLET (F), CHAMFER (CHA), ARRAY (AR), STRETCH (S), EXPLODE (X), BREAK (BR), JOIN (J)
Display	ZOOM (Z: window, all, extents), PAN (P), REGEN (RE)
Precision	ORTHO (F8), OSNAP (F3; endpoint, midpoint, centre, intersection, perpendicular, tangent, quadrant), POLAR (F10), OTRACK (F11), GRID (F7), SNAP (F9)
Annotation	DTEXT, MTEXT, DIMLINEAR, DIMALIGNED, DIMRADIUS, DIMDIAMETER, DIMANGULAR, QLEADER
Utility	LAYER (LA), PROPERTIES (Ctrl + 1), MATCHPROP (MA), DIST (DI), AREA (AA), LIST (LI), UNDO (U), REDO

Procedure

- **Exercise A (rectangle with a centre hole):** L → 0,0 → @80,0 → @0,50 → @-80,0 → C (close). C → pick the centre with the midpoint tracking of the sides or type 40,25 → radius 12.
- **Exercise B (regular hexagon of side 30):** POL → 6 → E (edge) → pick the first point → @30<0.
- **Exercise C (gasket):** draw two circles of diameter 40 and 20 at the centre; draw two circles of R10 at 50 mm on either side; join them with tangent lines using **LINE** with the **TAN** object snap; **TRIM** the unwanted arcs; draw holes Ø10 at the small centres.
- **Exercise D (array):** draw a circle of Ø80 and one small circle of Ø10 on its top quadrant; use **ARRAY** → **Polar**, centre = centre of the large circle, 8 items, 360° to make a flange pattern.
- **Exercise E (fillet and chamfer):** draw a 100 × 60 rectangle; **FILLET** with radius 10 on two corners; **CHAMFER** with distances 10, 10 on the other two.
- Use **OFFSET** to draw a parallel border 5 mm inside, **MIRROR** to complete symmetric shapes, and check a length with **DIST** and an area with **AREA**.
- Dimension all figures and save.

Precautions

- Read the command line prompts after every command.
- Keep ORTHO on for horizontal and vertical lines, and use object snaps instead of picking points by eye.
- Press Esc to cancel a wrong command and U to undo the last step.

Result



The AutoCAD interface was studied and simple figures were drawn and edited with draw, modify and precision commands.

Viva-voce questions

Q1. What is the full form of CAD? Name two CAD software packages.

Computer-aided design (or drafting). AutoCAD, SolidWorks, CATIA, Creo, Fusion 360, LibreCAD.

Q2. What is the difference between absolute and relative coordinates?

Absolute coordinates are measured from the origin (0,0); relative coordinates (prefix @) are measured from the last point.

Q3. What is the use of OSNAP?

Object snap locks the cursor exactly on geometric points of objects such as endpoints, midpoints, centres, intersections and tangency points.

Q4. What is the difference between TRIM and EXTEND?

TRIM cuts an object at a cutting edge; EXTEND lengthens an object up to a boundary edge.

Q5. What does OFFSET do?

It creates a parallel copy of a line, arc, circle or polyline at a given distance.

Q6. What is the file extension of an AutoCAD drawing and of a template?

.dwg for drawings, .dwt for templates (.dxf for drawing exchange).

Q7. Why are layers used?

To organise objects by type, and to control their colour, line type, line weight, visibility and plotting together.

Experiment 3: Scales — Plain and Diagonal Scales

Aim

To construct a plain scale and a diagonal scale for a given representative fraction and to mark given distances on them.

Requirements

Drawing instruments or AutoCAD.

Theory

A **scale** is the ratio of the length of an object on the drawing to its actual length. It is expressed by the **representative fraction (R.F.)**:

$$\text{R.F.} = \text{length on drawing} / \text{actual length (both in the same units)}$$

- **Full scale** 1 : 1; **reducing scales** 1 : 2, 1 : 5, 1 : 10, 1 : 50, 1 : 100 ...; **enlarging scales** 2 : 1, 5 : 1, 10 : 1 (for small parts such as watch components).
- **Length of scale** = R.F. $\times$ maximum length to be measured.
- A **plain scale** reads two units (e.g. metres and decimetres, or km and hectometres).
- A **diagonal scale** reads three units (e.g. metres, decimetres and centimetres), using the principle of similar triangles: a diagonal across one division, cut by 10 equally spaced horizontal lines, gives lengths of 1/10, 2/10 ... of the smallest division.
- **Vernier scales** also read three units, using the difference between a main-scale division and a vernier division.

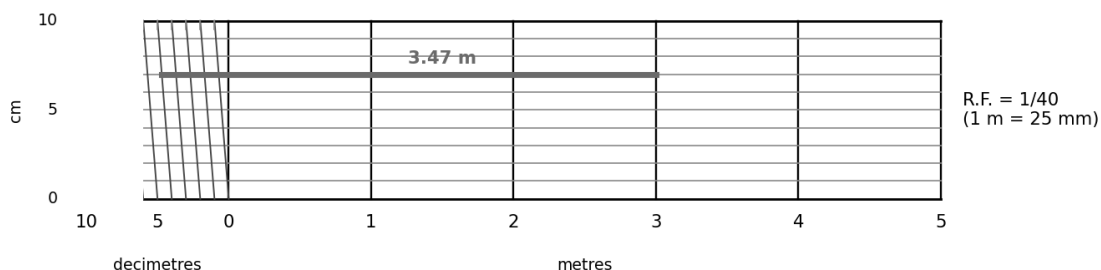


Figure 3.1: Diagonal scale of R.F. 1/40 reading metres, decimetres and centimetres, with a length of 3.47 m marked.

Worked example (diagonal scale)

Problem 1. Construct a diagonal scale of R.F. = 1/40 to read metres, decimetres and centimetres, long enough to measure up to 6 m. Mark a length of 3.47 m on it.

Length of scale = R.F. $\times$ maximum length = $(1/40) \times 6 \text{ m} = 0.15 \text{ m} = 150 \text{ mm}$.

Draw a line of 150 mm and divide it into 6 equal parts of 25 mm (each 1 m). Divide the first part into 10 equal parts (decimetres).

Erect a perpendicular of convenient height (say 25 mm) at the left end and divide it into 10 equal parts; draw horizontal lines through these points (centimetres).

Draw the diagonals in the first main division: join the bottom of each decimetre mark to the top of the next mark.

To mark 3.47 m: on the 7th horizontal line, measure from the vertical through 3 m to the diagonal through the 4th decimetre mark.

Answer: Scale length 150 mm; 3.47 m is shown in Figure 3.1.

Problem 2. The distance between two towns is 250 km and is represented by 5 cm on a map. Find the R.F. and the length of a scale to measure up to 600 km.

$$\text{R.F.} = 5 \text{ cm} / (250 \times 10^5 \text{ cm}) = 1/5,000,000.$$

$$\text{Length} = 600 \times 10^5 / 5,000,000 = 12 \text{ cm}.$$

Answer: R.F. = 1 : 5 × 10⁶; scale length 12 cm.

Problem 3. A plain scale of R.F. 1/50 is to read metres and decimetres up to 8 m. Find its length.

$$\text{Length} = 8 \text{ m} / 50 = 0.16 \text{ m}.$$

Answer: 160 mm (8 divisions of 20 mm, first division divided into 10).

Procedure (in AutoCAD)

- Draw the base line with L → 0,0 → @150,0 and the top line with OFFSET 25 (or @0,25).
- Use **DIVIDE** (DIV) on the base line with 6 segments (set **PDMODE** = 3 to see the points) and draw verticals through them with LINE and OSNAP node.
- Divide the first division into 10 with DIVIDE; divide the left vertical into 10 and draw horizontals using OFFSET 2.5 repeatedly or ARRAY (rectangular, 11 rows, spacing 2.5).
- Draw one diagonal and use **ARRAY** (rectangular, 1 row, 10 columns, spacing 2.5) to copy it.
- Write the figures with DTEXT (height 2.5–3.5) and mark the required length with a thick polyline.

Result

The plain and diagonal scales were constructed and the given lengths were marked.

Viva-voce questions

Q1. What is R.F.?

Representative fraction: the ratio of the drawing size to the actual size of the object, expressed with the same units.

Q2. When is an enlarging scale used?

For very small objects such as watch parts, electronic components and instrument details.



Q3. How many units can a diagonal scale read?

Three units (e.g. m, dm and cm).

Q4. On what principle is the diagonal scale based?

Similar triangles: the diagonal divides the short distances proportionally at each horizontal line.

Q5. What is a scale of chords used for?

For setting out or measuring angles without a protractor.

Experiment 4: Engineering Curves – Ellipse, Cycloid and Involute

Aim

To draw (a) an ellipse by the concentric circle method and the arcs of circles method, (b) a cycloid, and (c) the involute of a circle, and to draw a tangent and normal at a point on each.

Requirements

Drawing instruments, French curves; AutoCAD.

Theory

Conic sections: curves obtained when a right circular cone is cut by a plane.

Curve	Cutting plane	Eccentricity $e = (\text{distance from focus})/(\text{distance from directrix})$
Circle	Perpendicular to the axis	0
Ellipse	Inclined to the axis, cutting all generators	less than 1
Parabola	Parallel to a generator	equal to 1
Hyperbola	Parallel to the axis (or more steeply inclined than a generator)	greater than 1

Ellipse: the locus of a point moving so that the sum of its distances from two fixed points (foci) is constant and equal to the major axis. Foci lie on the major axis at a distance $\sqrt{a^2 - b^2}$ from the centre. Uses: arches, bridges, gears, elliptical tanks, planetary orbits.

Ellipse by the concentric-circle method (12 divisions)

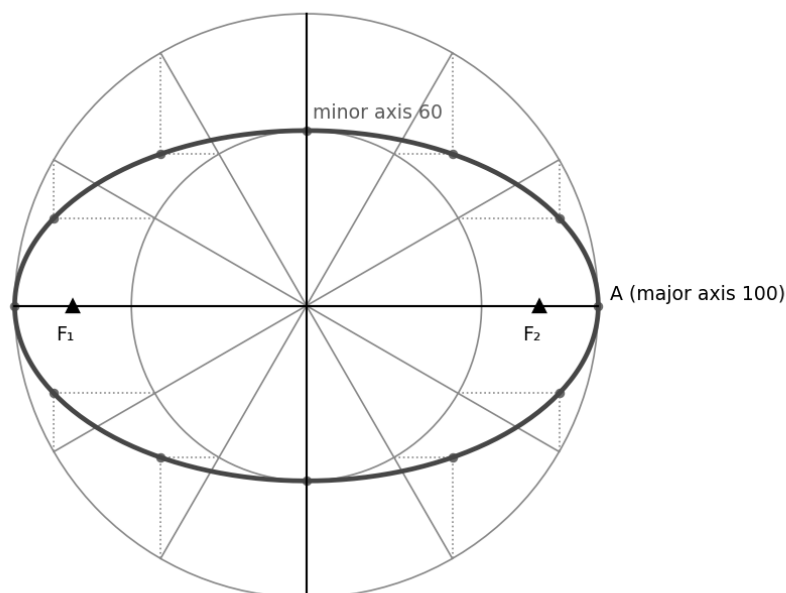


Figure 4.1: Ellipse with major axis 100 mm and minor axis 60 mm by the concentric circle method.

Roulettes: curves traced by a point on a circle rolling on a line or another circle.

- **Cycloid:** traced by a point on the circumference of a circle rolling without slipping on a straight line. The base length for one revolution is πD . Used in the profile of gear teeth (cycloidal gears) and in some arches.

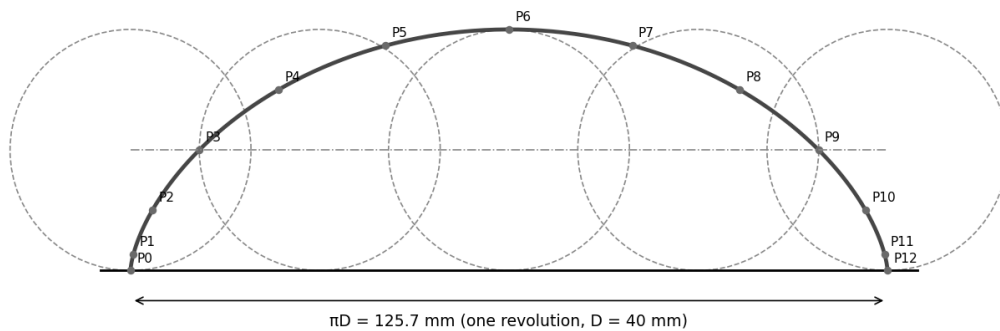


Figure 4.2: Cycloid traced by a point P on a rolling circle of diameter 40 mm.

- **Involute:** traced by the end of a taut string unwound from a circle (or polygon). Used in the profile of **involute gear teeth**, the most common gear profile.

Involute of a circle (D = 40 mm): tangents of length $(k/12) \cdot \pi D$

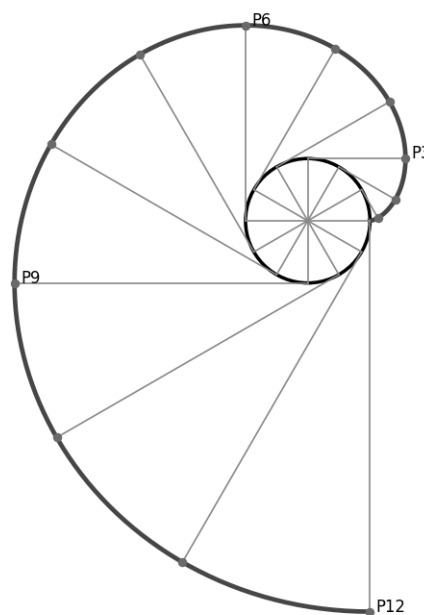


Figure 4.3: Involute of a circle of diameter 40 mm (one complete turn: final tangent length = $\pi D = 125.7$ mm).

Procedure — ellipse by the concentric circle method (manual and CAD)

- Draw the major axis AB = 100 mm and the minor axis CD = 60 mm bisecting each other at O.
- Draw two concentric circles with AB and CD as diameters.
- Divide the circles into 12 equal parts by radial lines (every 30°).
- From each point on the outer circle draw a vertical line; from the corresponding point on the inner circle draw a horizontal line. Their intersection is a point on the ellipse.
- Join the 12 points by a smooth curve (French curve); in AutoCAD use **SPLINE** through the points, or directly **ELLIPSE** (EL) → centre → axis endpoints.



- **Tangent and normal at a point P:** join P to the foci F_1 and F_2 ; the bisector of the angle F_1PF_2 is the normal; the tangent is perpendicular to it at P.

Procedure — cycloid

- Draw the rolling circle of diameter 40 mm touching the base line at P. Draw the base line $PQ = \pi D = 125.7$ mm.
- Divide the circle and PQ into 12 equal parts. Draw the locus of the centre (a line parallel to PQ through the centre) and mark the centre positions $C_1 \dots C_{12}$ above each division.
- Draw horizontal lines through the 12 points on the circle. With each centre C_k and radius 20 mm, cut the corresponding horizontal line to get P_k .
- Join $P_0 \dots P_{12}$ with a smooth curve (SPLINE in AutoCAD).

Procedure — involute of a circle

- Draw the circle ($D = 40$ mm), divide it into 12 parts and draw tangents at each point.
- On the tangent at point k, mark a length of $k \times \pi D/12$ ($k \times 10.47$ mm) from the point of tangency.
- Join the ends $P_1 \dots P_{12}$ by a smooth curve.
- **Normal:** at any point, the normal is the tangent from that point to the base circle; the tangent to the involute is perpendicular to it.

Result

The ellipse, cycloid and involute were drawn with tangents and normals at given points.

Viva-voce questions

Q1. Define eccentricity.

The ratio of the distance of a point on a conic from the focus to its distance from the directrix.

Q2. What is the eccentricity of a parabola?

Exactly 1.

Q3. Where are cycloidal and involute curves used?

In the profiles of gear teeth; involute gears are the most common because the centre distance can vary slightly without affecting the velocity ratio.

Q4. Give two practical uses of a parabola.

Reflectors of headlights and dish antennas, and the shape of cables of suspension bridges and arches.

Q5. What is the sum of the focal distances of any point on an ellipse?

It equals the major axis.

Q6. Which AutoCAD command draws a smooth curve through points?

SPLINE (SPL).

Experiment 5: Projection of Points and Straight Lines

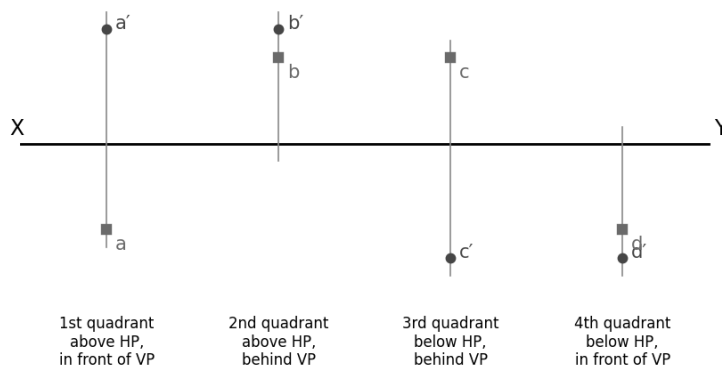
Aim

To draw the projections of points in different quadrants and of a straight line inclined to both the reference planes, and to find its true length and true inclinations.

Theory

Orthographic projection: the object is viewed from infinity (parallel projectors perpendicular to the plane of projection). Two principal planes are used: the **horizontal plane (HP)** and the **vertical plane (VP)**, meeting in the reference line **XY**. They form four quadrants.

- **Front view (elevation)** is projected on the VP; **top view (plan)** on the HP. Front views are named with dashed letters (a'), top views with plain letters (a).
- In **first-angle projection (BIS)**, the object is in the first quadrant: after rotating the HP, the **front view lies above XY and the top view below XY**.



First-angle method: front view ($'$) from height above HP; top view from distance in front of VP (plotted below XY).

Figure 5.1: Projections of points A, B, C and D lying in the four quadrants.

Position of point	Front view	Top view
1st quadrant (above HP, in front of VP)	above XY	below XY
2nd quadrant (above HP, behind VP)	above XY	above XY
3rd quadrant (below HP, behind VP)	below XY	above XY
4th quadrant (below HP, in front of VP)	below XY	below XY
On HP	on XY	below (or above) XY
On VP	above (or below) XY	on XY

Straight line inclined to both planes: true length TL, inclination θ to HP and ϕ to VP. The front view length is $TL \cos \phi$ and the top view length is $TL \cos \theta$; the apparent angles α (FV with XY) and β (TV with XY) are greater than θ and ϕ .

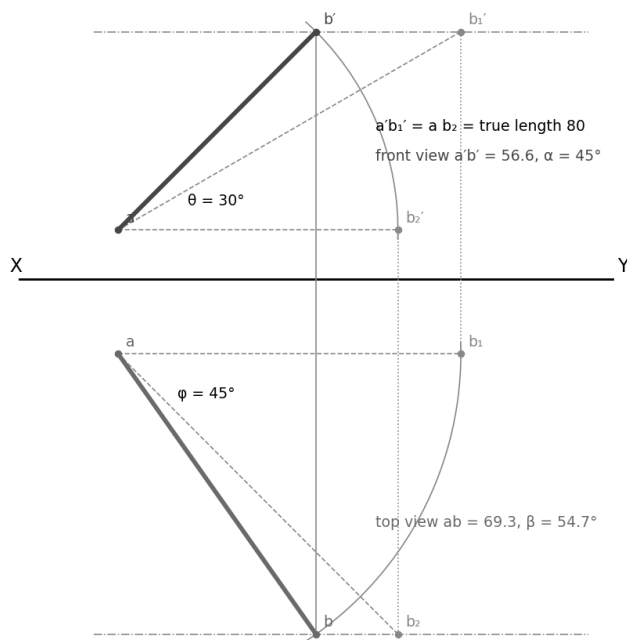


Figure 5.2: Line AB, 80 mm long, inclined at 30° to HP and 45° to VP, with A 10 mm above HP and 15 mm in front of VP.

Worked example

Problem 1. A line AB 80 mm long has its end A 10 mm above HP and 15 mm in front of VP. It is inclined at 30° to HP and 45° to VP. Draw its projections and find the lengths of the front and top views and their inclinations to XY.

Mark a' 10 mm above XY and a 15 mm below XY on the same projector.

Assume AB parallel to VP at $\theta = 30^\circ$: draw $a'b_1' = 80$ mm at 30° ; its top view ab_1 is parallel to XY, length $80 \cos 30^\circ = 69.3$ mm. The locus of b' is a horizontal line through b_1' (50 mm above XY).

Assume AB parallel to HP at $\phi = 45^\circ$: draw $ab_2 = 80$ mm at 45° below the line through a ; its front view $a'b_2' = 80 \cos 45^\circ = 56.6$ mm. The locus of b is a horizontal line through b_2 (71.6 mm below XY).

With a as centre and radius $ab_1 = 69.3$ mm, cut the locus of b at b ; with a' as centre and radius $a'b_2' = 56.6$ mm, cut the locus of b' at b' . Check that b and b' lie on one projector (40 mm to the right of a).

Answer: Front view $a'b' = 56.6$ mm at $\alpha = 45^\circ$; top view $ab = 69.3$ mm at $\beta = 54.7^\circ$.

Procedure (in AutoCAD)

- Draw XY with L; use OFFSET to place the loci lines at 10, 15, 50 and 71.6 mm.
- Use relative polar input for the true-length lines: from a' , @80<30; from a , @80<-45.
- Draw circles (C) of radius 69.3 centred at a and 56.6 centred at a' to intersect the loci; use **TRIM** to leave only the required arcs.
- Join the final points with PLINE of width 0.5 on the OUTLINE layer; measure lengths with DIST and angles with DIMANGULAR.



Result

Projections of the points and the line were drawn; FV = 56.6 mm, TV = 69.3 mm, $\alpha = 45^\circ$, $\beta = 54.7^\circ$.

Viva-voce questions

Q1. Why is first-angle projection used in India?

It is recommended by BIS (SP 46) and followed by ISO in many countries; third-angle projection is used in the USA.

Q2. Where does the top view of a point lying in the second quadrant appear?

Above XY (both views appear above XY, so they may overlap).

Q3. When does a line show its true length in the front view?

When it is parallel to the VP.

Q4. What is a trace of a line?

The point where the line (produced if necessary) meets a reference plane: the horizontal trace on HP and the vertical trace on VP.

Q5. If a line is perpendicular to HP, what are its views?

The top view is a point and the front view shows the true length perpendicular to XY.

Experiment 6: Projection of Planes

Aim

To draw the projections of regular plane figures (square, pentagon, hexagon, circle) inclined to one reference plane.

Theory

A plane figure (lamina) has only length and breadth. Its projections depend on its position:

Position of the plane	Front view	Top view
Parallel to HP (perpendicular to VP)	Line parallel to XY	True shape
Parallel to VP (perpendicular to HP)	True shape	Line parallel to XY
Inclined to HP at θ , perpendicular to VP	Line at θ to XY	Reduced (foreshortened) shape
Inclined to VP at ϕ , perpendicular to HP	Reduced shape	Line at ϕ to XY
Inclined to both planes	Reduced shape	Reduced shape

Method (change of position): draw the plane first in a simple position where it shows its true shape, tilt it in the second stage to the required angle (the edge view is inclined), and project the reduced view by projectors and loci.

Worked example

Problem 1. A regular hexagonal plate of 30 mm side rests on one of its sides on HP, with that side perpendicular to VP. The surface is inclined at 45° to HP. Draw its projections.

Stage 1: assume the plate lies on HP. Draw the true shape (hexagon) in the top view with the resting side perpendicular to XY; the front view is a line on XY whose length is the distance across flats, $\sqrt{3} \times 30 = 52$ mm.

Stage 2: tilt the 52 mm front-view line about the resting end so that it makes 45° with XY.

Project vertically from the new front view and horizontally from the stage-1 top view; the intersections give the new top view, whose length along XY is $52 \cos 45^\circ = 36.8$ mm while the width (corner to corner, 60 mm) is unchanged.

Answer: The front view is a 52 mm line at 45° ; the top view is a reduced hexagon 36.8 mm long and 60 mm wide.

Procedure (in AutoCAD)

- Draw the true shape with **POLYGON** (6 sides, edge option). Draw the edge view line.
- Use **ROTATE** (RO) with the base point at the resting edge to tilt the edge view by 45° .
- Draw projectors with **ORTHO** on and use **XLINE** (construction lines) through the corners; find intersections and join them with **PLINE**.

Result



The projections of the hexagonal plate inclined to HP were drawn.

Viva-voce questions

Q1. When does a plane show its true shape?

When it is parallel to the plane of projection.

Q2. What is the edge view of a plane?

The view in which the plane appears as a line, when it is perpendicular to the plane of projection.

Q3. What is the length of the diagonal of a regular hexagon of side a ?

$2a$ (corner to corner); across the flats it is $\sqrt{3} a$.

Q4. Why are planes drawn in stages?

Because the true shape is known only in a simple position; the inclination is then introduced one plane at a time.

Experiment 7: Projection of Solids

Aim

To draw the projections of prisms, pyramids, cylinders and cones with their axes (a) perpendicular to HP and (b) inclined to HP.

Theory

Classification of solids:

- **Polyhedra:** prisms (triangular, square, pentagonal, hexagonal), pyramids, and regular polyhedra (tetrahedron, cube, octahedron).
- **Solids of revolution:** cylinder, cone, sphere.
- **Frustum:** part of a cone or pyramid left after cutting off the top by a plane parallel to the base. **Truncated:** cut by an inclined plane.

Rules: when the axis is perpendicular to HP, the top view shows the true shape of the base and is drawn first; when the axis is perpendicular to VP, the front view is drawn first. For an axis inclined to HP, draw the solid first with its axis perpendicular to HP (stage 1), then tilt the front view to the required angle (stage 2) and project the new top view.

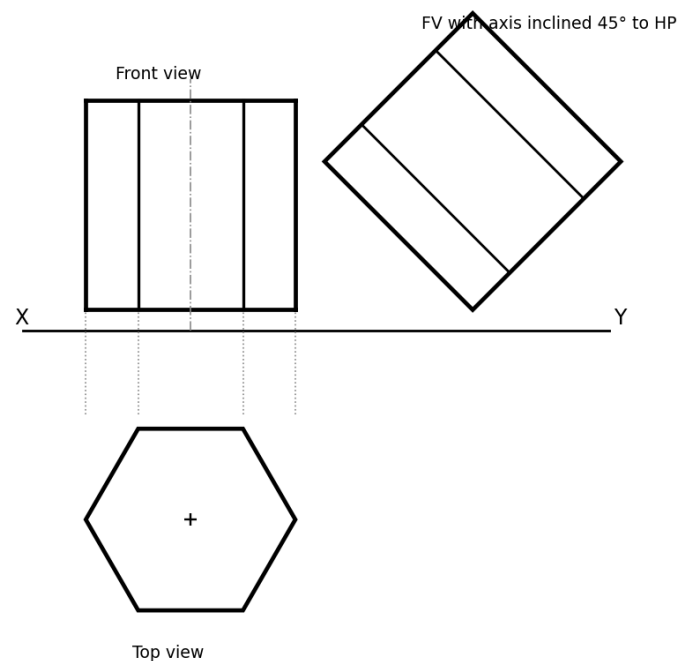


Figure 7.1: Hexagonal prism, base side 25 mm, axis 50 mm: (left) resting on its base on HP with two faces parallel to VP; (right) the front view with the axis inclined at 45° to HP.

Worked example

Problem 1. A hexagonal prism, side of base 25 mm and axis 50 mm long, rests on its base on HP with two of its rectangular faces parallel to VP. Draw its projections.

Draw the top view first: a regular hexagon of side 25 mm with two sides parallel to XY (corner-to-corner distance 50 mm along XY).



Project the corners upwards; the front view is a rectangle 50 mm wide and 50 mm high, with two interior vertical lines (the visible edges) at 12.5 mm on either side of the axis.

Answer: Top view: hexagon; front view: rectangle 50 × 50 mm divided into three faces (widths 12.5, 25, 12.5 mm).

Procedure (in AutoCAD)

- Draw the hexagon with POLYGON (inscribed option, radius 25) and rotate it if needed so that two sides are parallel to XY.
- Draw vertical XLINES from each corner; draw the base line and top line of the front view 50 mm apart using OFFSET.
- TRIM the construction lines; put the axis on the CENTER layer and any hidden edges on the HIDDEN layer.
- For the inclined position, select the front view and **ROTATE** it about the resting corner by the required angle; project the new top view with XLINES from the rotated front view and horizontal lines from the stage-1 top view.

Result

The projections of the hexagonal prism in the given positions were drawn.

Viva-voce questions

Q1. What is the difference between a prism and a pyramid?

A prism has two equal, parallel end faces joined by rectangular faces; a pyramid has one base and triangular faces meeting at the apex.

Q2. Which view is drawn first if the axis of a solid is perpendicular to HP?

The top view, since it shows the true shape of the base.

Q3. What is a frustum?

The portion of a cone or pyramid between the base and a cutting plane parallel to the base.

Q4. What is a generator of a cone?

A straight line joining the apex to a point on the circumference of the base.

Q5. How are hidden edges shown?

With dashed thin lines (HIDDEN line type in AutoCAD).

Experiment 8: Sections of Solids and True Shape of the Section

Aim

To draw the sectional views of a solid cut by a section plane and to find the true shape of the section.

Theory

A **section plane (cutting plane)** is an imaginary plane that cuts the object to show its interior. The part between the observer and the plane is removed. The cut surface is **hatched** with thin lines at 45° , about 1–2 mm apart.

Section plane	Sectional view	True shape seen in
Parallel to HP (horizontal)	Sectional top view	Top view
Parallel to VP	Sectional front view	Front view
Perpendicular to VP, inclined to HP (auxiliary inclined plane)	Sectional top view (reduced)	Auxiliary view on a plane parallel to the section plane
Perpendicular to HP, inclined to VP	Sectional front view (reduced)	Auxiliary view

The cutting plane is shown in the view where it appears as a line, with a chain line thick at the ends (type H).

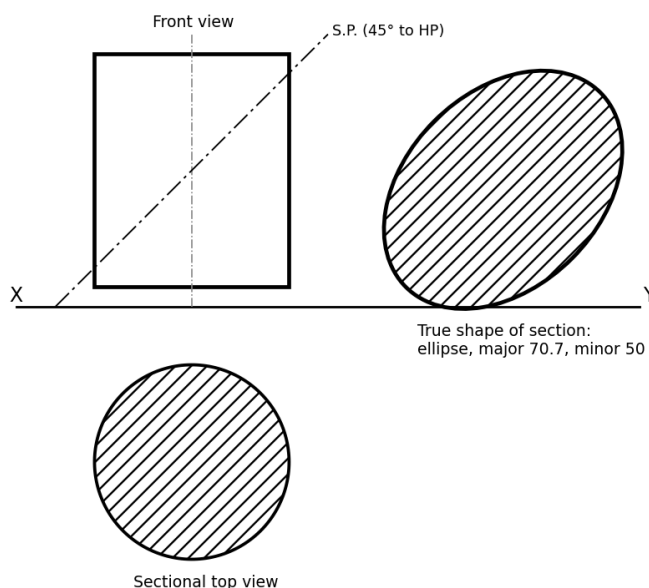


Figure 8.1: Cylinder ($\varnothing 50$, height 60) cut by a section plane inclined at 45° to HP through the midpoint of the axis: front view, sectional top view and true shape (ellipse).

Worked example

Problem 1. A cylinder of diameter 50 mm and height 60 mm stands on its base on HP. It is cut by a section plane perpendicular to VP, inclined at 45° to HP, passing through the midpoint of the axis. Draw the front view, sectional top view and true shape of the section.

Draw the top view (circle $\varnothing 50$) and the front view (rectangle 50×60). Divide the circle into 12 parts and draw the generators in the front view.

Draw the section plane line at 45° through the mid-point of the axis (30 mm above HP). It cuts all 12 generators between heights 5 and 55 mm, so the section is a complete ellipse.

The sectional top view is the full circle (all generators are cut), hatched.

For the true shape, draw a reference line parallel to the section line; project the cut points perpendicular to it and mark their distances from the axis measured in the top view.

Answer: True shape: an ellipse with major axis $50/\cos 45^\circ = 70.7$ mm and minor axis 50 mm.

Procedure (in AutoCAD)

- Draw the views; draw the section line with @100<45 and move it to pass through the axis midpoint.
- Divide the circle with DIVIDE (12) and draw generators with XLINE.
- Find intersections of the section line with the generators; draw a parallel auxiliary reference line with OFFSET and project points perpendicular to the section line (POLAR at 135°).
- Join the points with SPLINE (or use ELLIPSE with the axis endpoints); use **HATCH** (pattern ANSI31, scale 1) to hatch the section.

Result

The sectional views and the true shape of the section (ellipse 70.7×50 mm) were drawn.

Viva-voce questions

Q1. Why are sectional views drawn?

To show the interior details of an object clearly without many hidden lines.

Q2. What is hatching? At what angle is it drawn?

Thin parallel lines drawn on the cut surface, usually at 45° to the outline or axis.

Q3. What is the true shape of a section of a cylinder cut by a plane inclined to its axis?

An ellipse (if all generators are cut).

Q4. What is the true shape of a section of a cone cut by a plane parallel to a generator?

A parabola.

Q5. Which AutoCAD command is used for hatching?

HATCH (H) or BHATCH, with patterns such as ANSI31.

Experiment 9: Development of Lateral Surfaces of Solids

Aim

To draw the development of the lateral surfaces of a cylinder, a prism and a cone.

Theory

Development is the unfolding of the surface of a solid onto a flat plane, showing the true size of every face. It is used in sheet-metal work: ducts, chimneys, hoppers, funnels, tanks, buckets, boxes and transition pieces.

Method	Used for
Parallel-line development	Prisms and cylinders
Radial-line development	Pyramids and cones
Triangulation	Transition pieces
Approximate method	Spheres (double-curved surfaces)

Cylinder: rectangle of length πD and height H . Cone: sector of radius L (slant height) and angle $\theta = 360^\circ \times r/L$

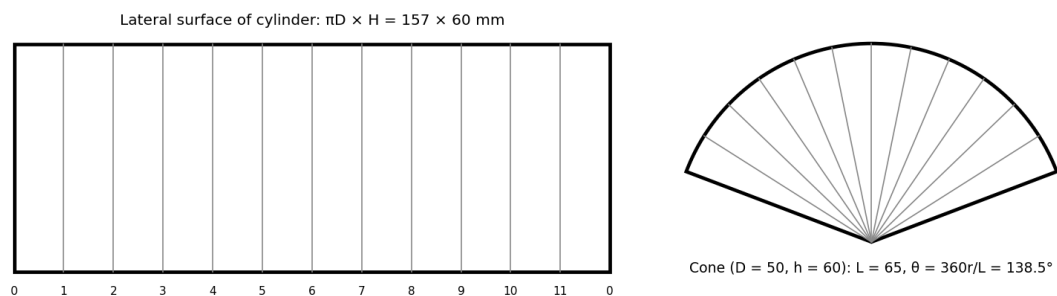


Figure 9.1: Development of the lateral surfaces of a cylinder ($D = 50$, $H = 60$) and a cone ($D = 50$, $h = 60$).

Worked example

Problem 1. Draw the development of the lateral surface of (a) a cylinder of diameter 50 mm and height 60 mm, (b) a cone of base diameter 50 mm and height 60 mm.

(a) Length $= \pi D = \pi \times 50 = 157.1$ mm; draw a rectangle 157.1×60 mm and divide it into 12 parts for the generators.

(b) Slant height $L = \sqrt{(25^2 + 60^2)} = 65$ mm. Sector angle $\theta = 360 \times 25/65 = 138.5^\circ$.

Draw an arc of radius 65 mm subtending 138.5° and join its ends to the centre; divide the arc into 12 parts for the generators.

Answer: Cylinder: 157.1×60 mm rectangle; cone: sector of radius 65 mm and angle 138.5° .

Problem 2. Find the development of a square prism of base side 30 mm and height 50 mm.

Four rectangles of 30×50 mm side by side.



Answer: A rectangle 120×50 mm divided into four faces (plus two 30×30 squares for the ends if required).

Procedure (in AutoCAD)

- Cylinder: REC $\rightarrow$ @157.08,60; use DIVIDE with 12 segments on the base and draw verticals.
- Cone: draw the arc with **ARC $\rightarrow$ Centre, Start, Angle** (angle 138.5) with radius 65; draw the two radii; divide the arc with DIVIDE 12 and join to the centre.
- Label the generators 0, 1, 2 ... 12 and dimension the development.

Result

The developments of the lateral surfaces of the cylinder, prism and cone were drawn.

Viva-voce questions

Q1. What is development of surfaces?

The unrolling of the surface of a solid on a plane, showing its true size and shape.

Q2. Which method is used for developing a cone?

Radial-line development.

Q3. Can a sphere be developed exactly?

No; it is a double-curved surface, so only approximate developments (zones or lunes) are possible.

Q4. Give two industrial uses of development.

Making sheet-metal ducts, funnels, chimneys, buckets, boxes and hoppers.

Q5. What is the sector angle for a cone whose slant height equals its base diameter?

$$\theta = 360 \times r/L = 360 \times r/(2r) = 180^\circ.$$

Experiment 10: Isometric Scale and Isometric View

Aim

To construct an isometric scale and draw the isometric view of a simple block from its orthographic views.

Theory

Isometric projection is a pictorial projection in which the three principal axes are equally inclined to the plane of projection, so they appear at 120° to each other: one vertical and two at 30° to the horizontal.

- Lengths along the isometric axes are reduced to **0.816** of the true length ($\sqrt{2}/\sqrt{3}$); this reduced length is the **isometric length**, and a drawing made with it is an **isometric projection**.
- When true lengths are used (for convenience), the drawing is an **isometric view (isometric drawing)**; it is about 22.5% larger than the isometric projection but has the same shape.
- Lines parallel to the isometric axes are **isometric lines**; only these can be measured. Circles appear as ellipses (drawn by the four-centre method).

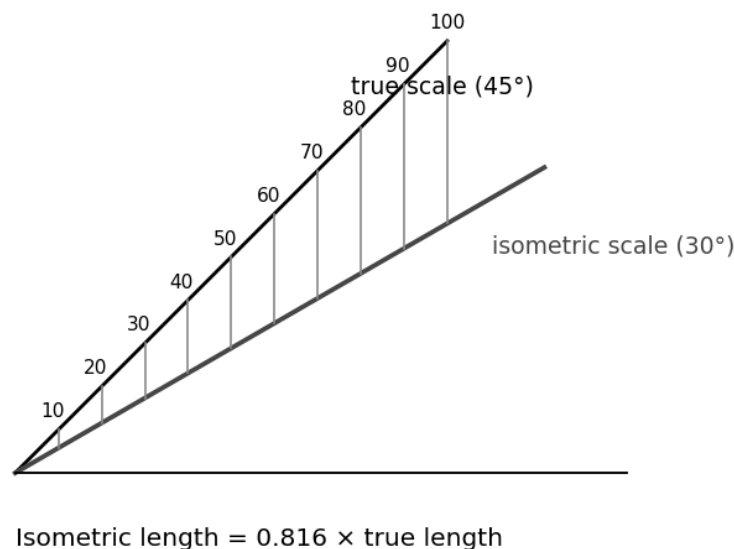


Figure 10.1: Construction of an isometric scale: true lengths on a 45° line are projected vertically onto a 30° line.

Isometric view of an L-block: base $60 \times 40 \times 20$, upright $20 \times 40 \times 40$

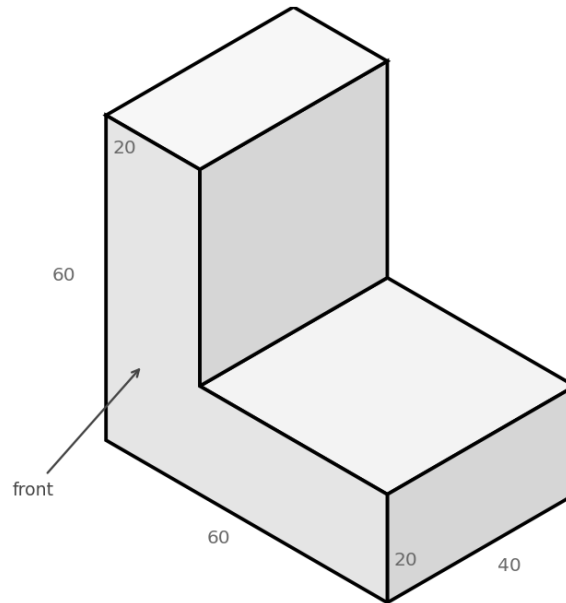


Figure 10.2: Isometric view of an L-block (base $60 \times 40 \times 20$ mm with an upright $20 \times 40 \times 40$ mm at one end).

Procedure (in AutoCAD)

- Type **DSETTINGS** (DS) → Snap and Grid tab → select **Isometric snap**; or click the isometric drafting button on the status bar.
- Switch between the isoplanes (left, top, right) with **F5** (or Ctrl + E). Keep ORTHO (F8) on.
- Draw the base box: from a start point draw 60 along the right isometric axis, 40 along the left axis and 20 vertically, and close the faces.
- Draw the upright at one end: $20 \times 40 \times 40$ above the base.
- **TRIM** the hidden lines; draw isometric circles (if any) with **ELLIPSE** → **Isocircle**.
- Dimension with **DIMALIGNED** and use **DIMEDIT** → **Oblique** (30° or 150°) to align the extension lines with the isometric axes.

Result

The isometric scale and the isometric view of the L-block were drawn.

Viva-voce questions

Q1. What is the ratio of isometric length to true length?

0.816 (about 9 : 11).

Q2. What is the difference between isometric projection and isometric view?

Isometric projection uses the reduced isometric scale; the isometric view uses true lengths and is larger but of the same shape.

Q3. At what angle are the isometric axes inclined to each other?

At 120° .



Q4. How does a circle appear in isometric view?

As an ellipse (isocircle).

Q5. Which key toggles isoplanes in AutoCAD?

F5 (or Ctrl + E).

Experiment 11: Orthographic Views from a Pictorial View

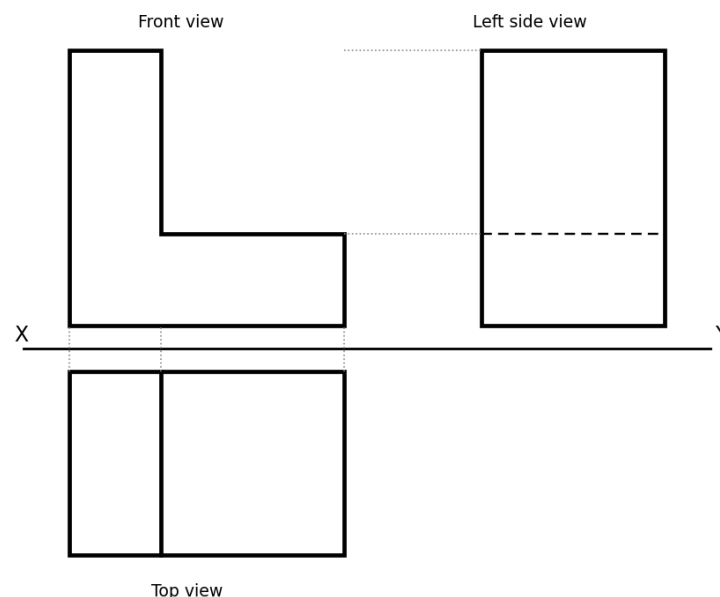
Aim

To draw the front view, top view and left side view of a given pictorial object in first-angle projection.

Theory

Conversion of pictorial views: the arrow in the pictorial view shows the direction of viewing for the front view. The views are drawn as follows in first-angle projection:

- **Front view (FV):** looking along the arrow; drawn at the top left.
- **Top view (TV):** looking from above; drawn **below** the front view.
- **Left side view (LSV):** looking from the left of the object; drawn on the **right** of the front view.
- The height is common to FV and side view, the length is common to FV and TV, and the width is common to TV and side view (transferred with a 45° mitre line).
- Hidden edges are shown by dashed lines; axes of holes and curved surfaces by centre lines.



First-angle projection: TV below FV; left side view on the right of FV.

Figure 11.1: Front view, top view and left side view of the L-block of Figure 10.2 in first-angle projection. The hidden base edge appears dashed in the side view.

Procedure (in AutoCAD)

- Draw XY and the front view first with PLINE using relative coordinates: 0,0 → @60,0 → @0,20 → @-40,0 → @0,40 → @-20,0 → C.
- Draw vertical XLINES from the FV corners to construct the TV below XY (depth 40).
- Draw horizontal XLINES from the FV to construct the side view on the right; transfer the depth with a 45° mitre line (XLINE at 45° or 135°).
- TRIM the construction lines, assign line types (OUTLINE, HIDDEN, CENTER) and dimension each view without repeating dimensions.
- Add the title block with the first-angle symbol and plot.



Result

The three orthographic views of the given object were drawn in first-angle projection.

Viva-voce questions

Q1. In first-angle projection where is the left side view placed?

On the right-hand side of the front view.

Q2. Which dimensions are common to the front and top views?

The length (horizontal dimensions).

Q3. What is a mitre line?

A 45° line used to transfer depths between the top view and the side view.

Q4. Why are at least two views needed to describe an object?

One view shows only two dimensions; the third dimension (depth) must come from another view.

Experiment 12: Building Drawing — Plan of a Room and Mini Project

Aim

To draw the plan of a single room with doors and windows using AutoCAD, and to complete a mini project (a two-dimensional drawing of a machine part or a simple residential plan) with layers, dimensions, blocks and a title block.

Theory

Building drawing conventions (IS 962): walls are drawn with two parallel thick lines at the wall thickness (230 mm for one-brick walls, 115 mm for partitions); openings are shown by breaking the walls; doors by a thin arc showing the swing; windows by thin lines inside the wall thickness. Standard sizes: door 1.0×2.1 m, window 1.2×1.2 m, ventilator 0.6×0.45 m. Drawings are usually plotted at 1 : 50 or 1 : 100.

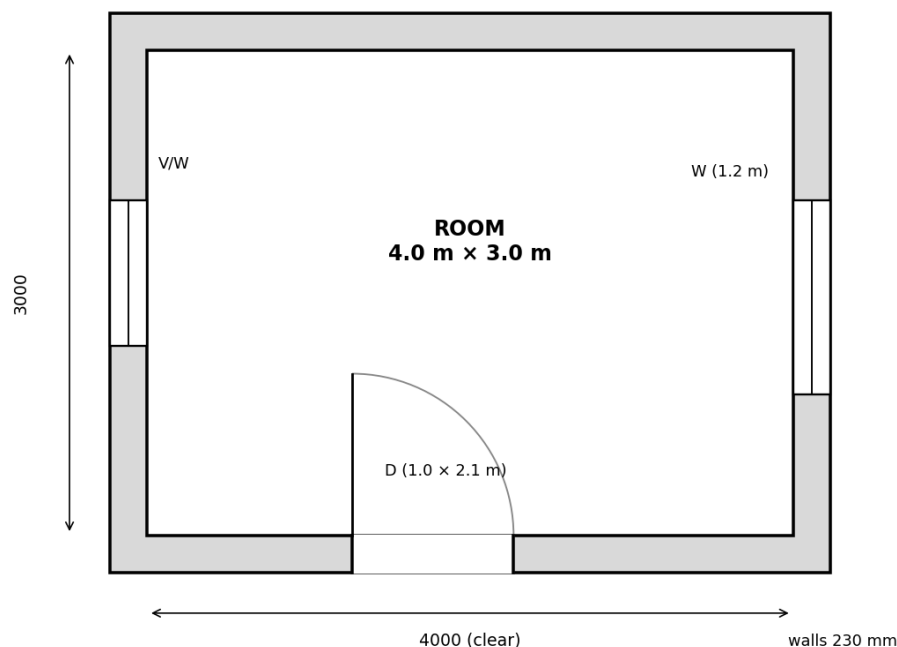


Figure 12.1: Plan of a $4.0 \text{ m} \times 3.0 \text{ m}$ room with 230 mm walls, one door, one window and one ventilator.

Blocks: a block is a named group of objects (door, window, bolt, symbol) that can be inserted many times with **INSERT**. Blocks save time and keep drawings consistent.

Attributes attach text data (e.g. part number) to blocks.

Procedure (in AutoCAD)

- Set units to millimetres. Draw the inner wall with REC $\rightarrow 0,0 \rightarrow @4000,3000$ and the outer wall with OFFSET 230 outwards.
- Break the walls for the door (1000 mm) with **BREAK** or by drawing lines and TRIM; draw the door leaf as a line of 1000 mm and the swing with ARC.
- Draw one window (1200 mm) and one ventilator; make each a **BLOCK** (B) and insert copies where needed.
- Hatch the walls (ANSI31 or SOLID) on a separate layer; add room names with MTEXT (height 200 for 1 : 50 plotting).
- Dimension with a dimension style scaled for 1 : 50 (**DIMSCALE** = 50).



- Switch to a **Layout** tab, create a viewport with **MVIEW**, set the viewport scale to 1 : 50, insert the title block, and plot to PDF (DWG To PDF.pc3).
- **Mini project (any one):** plan of a two-room house with kitchen and toilet; front view and top view of a flange coupling; a V-block; an electrical circuit layout; the student's own design.

Result

The plan of a room and a mini project drawing were prepared and plotted with a title block.

Viva-voce questions

Q1. What is a block in AutoCAD?

A named group of objects stored as one object that can be inserted repeatedly.

Q2. What is the difference between model space and paper space (layout)?

Model space is where the object is drawn at full size; paper space (layout) arranges scaled views, title blocks and notes for printing.

Q3. What is the standard thickness of a one-brick wall?

230 mm (200 mm with modular bricks).

Q4. How is a 1 : 100 scale set for plotting?

By setting the viewport scale (or plot scale) to 1 : 100 (1 mm on paper = 100 mm drawing units) and scaling text and dimensions accordingly.

Q5. Why is plotting to PDF useful?

The drawing can be viewed and printed on any computer without AutoCAD, with exact scale and line weights.



Appendix A: AutoCAD Command Quick Reference

Command	Alias	What it does
LINE	L	Draws straight line segments
PLINE	PL	Draws a polyline (connected lines and arcs as one object; can have width)
CIRCLE	C	Circle by centre-radius, diameter, 2P, 3P or TTR (tangent-tangent-radius)
ARC	A	Arc by three points, start-centre-end, centre-start-angle, etc.
RECTANG	REC	Rectangle by two corners; options for chamfer, fillet, width
POLYGON	POL	Regular polygon, inscribed or circumscribed about a circle, or by edge
ELLIPSE	EL	Ellipse by axis endpoints or centre; isocircle in isometric mode
SPLINE	SPL	Smooth curve through fit points
XLINE	XL	Infinite construction line (horizontal, vertical, angular, bisector)
HATCH	H	Fills an enclosed area with a pattern (ANSI31 for sections)
DIVIDE / MEASURE	DIV / ME	Places points at equal divisions / at a fixed distance
MOVE / COPY	M / CO	Moves or copies objects by base point and displacement
ROTATE / SCALE	RO / SC	Rotates about a base point / resizes by a factor
MIRROR	MI	Creates a mirror image about a line
OFFSET	O	Parallel copy at a given distance
TRIM / EXTEND	TR / EX	Cuts at / lengthens up to a boundary
FILLET / CHAMFER	F / CHA	Rounds / bevels a corner
ARRAY	AR	Rectangular, polar or path copies
STRETCH	S	Stretches objects crossed by a crossing window
EXPLODE / JOIN	X / J	Breaks compound objects into parts / joins objects



Command	Alias	What it does
LAYER	LA	Creates and controls layers
DIMLINEAR, DIMALIGNED	DLI, DAL	Linear and aligned dimensions
DIMRADIUS, DIMDIAMETER, DIMANGULAR	DRA, DDI, DAN	Radius, diameter and angle dimensions
MTEXT / DTEXT	T / DT	Paragraph text / single-line text
BLOCK / INSERT	B / I	Creates / inserts a block
ZOOM / PAN	Z / P	Changes the view
DIST / AREA / LIST	DI / AA / LI	Measures distance, area; lists properties
PLOT	Ctrl + P	Prints the drawing

Function keys: F1 help, F2 text window, F3 object snap, F5 isoplane, F7 grid, F8 ortho, F9 snap, F10 polar, F11 object snap tracking, F12 dynamic input.



Appendix B: Model Viva and Lab Examination Questions

Short questions with answers

Q1. What is engineering drawing called and why?

The "language of engineers", because it communicates the shape, size and specifications of objects precisely and universally.

Q2. What is the difference between first-angle and third-angle projection?

In first-angle the object is between the observer and the plane: TV is below FV and LSV on the right. In third-angle the plane is between the observer and the object: TV is above FV and LSV on the left.

Q3. What is an auxiliary view?

A view projected on a plane parallel to an inclined surface (auxiliary plane), to show its true shape.

Q4. Define locus.

The path traced by a point moving under given conditions, e.g. an ellipse is the locus of a point whose sum of distances from two foci is constant.

Q5. What is a helix?

The curve traced by a point moving around a cylinder (or cone) with uniform angular speed and uniform axial speed; used for screw threads and springs.

Q6. What are the principal views of an object?

Front view, top view and side views (left and right), plus the bottom and rear views when required.

Q7. What is meant by a section plane "perpendicular to VP and inclined to HP"?

It appears as a line inclined to XY in the front view; its true shape is found on an auxiliary inclined plane.

Q8. Which drawing shows three faces of an object in one view?

A pictorial drawing such as an isometric or oblique view.

Q9. What is the use of the UCS in AutoCAD?

The user coordinate system sets the origin and direction of axes for convenient input of coordinates, especially in 3D.

Q10. What is the extension of an AutoCAD backup file?

.bak (autosave files are .sv\$).

Sample lab examination problems



- Draw a diagonal scale of R.F. 1 : 2500 to read up to 1 km and to read metres on it. Show a length of 776 m.
- Draw an ellipse with a major axis of 120 mm and a minor axis of 80 mm by the arcs-of-circles method. Draw a tangent and normal at a point 30 mm from the centre along the major axis.
- A line PQ 75 mm long has P 15 mm above HP and 20 mm in front of VP. It is inclined at 30° to HP and 40° to VP. Draw its projections and find the apparent angles.
- A pentagonal pyramid, base side 30 mm and axis 60 mm, rests on one base edge on HP with the axis inclined at 30° to HP and parallel to VP. Draw its projections.
- A cone of base diameter 60 mm and axis 70 mm stands on HP and is cut by a plane perpendicular to VP, inclined at 45° to HP and passing through the midpoint of the axis. Draw the sectional top view and the true shape of the section, and the development of the remaining lateral surface.
- Draw the isometric view of a cylinder of diameter 50 mm and height 60 mm resting on its base on HP.
- Draw the front view, top view and left side view of a given machine block and dimension them (first-angle projection).

Answer outline for the diagonal scale problem

Problem 1. Diagonal scale of R.F. 1 : 2500 to read up to 1 km (metres); show 776 m.

Length of scale = $1000 \text{ m} \times 1/2500 = 0.4 \text{ m} = 400 \text{ mm}$ (fits an A3 sheet in landscape). Divide it into 10 main divisions of 40 mm, each representing 100 m.

Divide the first division into 10 parts (10 m each) and draw 10 horizontal lines with diagonals (1 m each).

For 776 m: on the 6th horizontal line, measure from the vertical through 700 m to the diagonal through the 7th small division (70 m).

Answer: 776 m = 700 + 70 + 6 m, read on the 6th horizontal line.