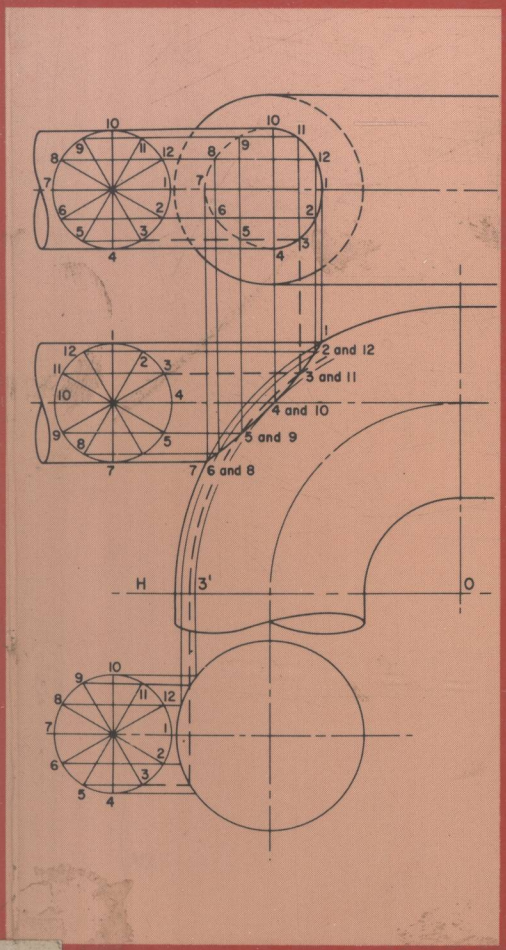
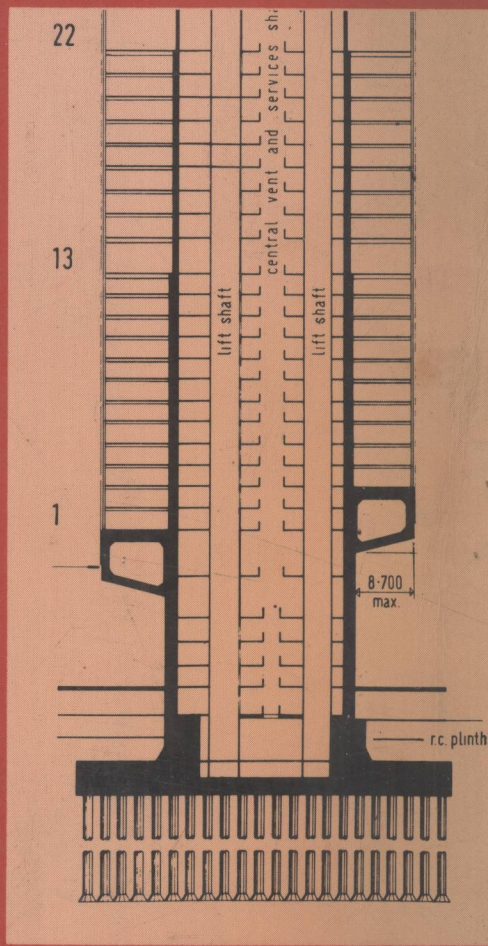
Civil Engineering Drawing

SECOND EDITION





V Jude

evised by Robert B Matkin

Civil Engineering Drawing

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Second Edition

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ILLUSTRATIONS

PREFACE TO FIRST EDITION

The last quarter of the twentieth century will see more construction than ever before in the history of mankind. More people will require better accommodation, transport systems, and recreational facilities. As civil engineers, we are responsible for the basis of the environment that man has come to accept; we design and build his roads, docks, and airports; we provide him with water and remove his sewage; we also play a large part in providing him with gas and electricity. For this to be done more quickly, more efficiently, and more cheaply than in the past, there must be a constant interchange of ideas and precise information between all engineering disciplines and all nations.

It is here that engineering drawing comes into its own as the undisputed international language of the engineer. A language that must be acquired by the student of civil engineering as soon as possible.

The aim of this book is to teach some of the fundamentals of this language in a straightforward way, for the civil engineering student has, in the past, lacked books dealing specifically with engineering drawing. There are many good books concerned with projection and geometry, as well as others incorporating 'engineering drawing' in the title, but no book known to the author has attempted to provide primarily for the needs of the civil engineer.

The content of all technological courses increases year by year and time must be saved somewhere. This can be done, to some extent, if all the student's exercises, including drawing, are concerned with civil engineering, so that he begins to see and think professionally from the start.

Although the later sections of this book, which discuss drawing in practice, may not affect the student immediately, they are intended to give him a background to the role of drawing in civil engineering and should help to explain why things are done in the way they are. It is hoped that the photographs of schemes and structures will play a part in conveying how exciting and challenging the field can be.

Several references are made in the text to the necessity of saving time, since skilled men's time is so expensive, and to the need to reduce errors and chances of ambiguity. To this end, the student should familiarize himself at an early stage with the appropriate British Standards, references to which are given in the text.

Acknowledgements

The sources of the photographs and the working drawings reproduced facsimile are included in their captions. While gratefully acknowledging permission to use this material, I should also like to thank many other individuals for so willingly giving their time in correspondence and discussion.

In addition, extracts from BS4: *1962, Part 1, Specification for Structural Steel Sections:* BS 308: *1964, Engineering Drawing Practice;* BS 1192: *1953, Drawing Office Practice for Architects and Builders;* and BS 3429: *1961, Specification for Sizes of Drawing Sheets* are reproduced by permission of the British Standards Institution, 2 Park Street, London, W1 from whom copies of the complete standards may be obtained.

D. V. Jude

PREFACE TO SECOND EDITION

In the eleven years since the late Mr Jude prepared the book for publication, there has been a great change in the commercial preparation of drawings. Computerised draughting machines are now replacing many of the routine tasks formerly undertaken by draughtsmen and tracers.

New types of draughting equipment, compass, scales, pencil lead holders and drawing pens appear regularly, but fundamentally they perform the same tasks under the skilled hands of the operator.

There is no change however in the basics of engineering drawing, orthographic and pictorial projection, geometrics, developments and intersections, conics and the practice of drawing at the board. The only way to the understanding of drawings and to good draughtsmanship is to practise the art constantly, for art it is and one where practice, practice and more practice is the only way towards reaching near perfection.

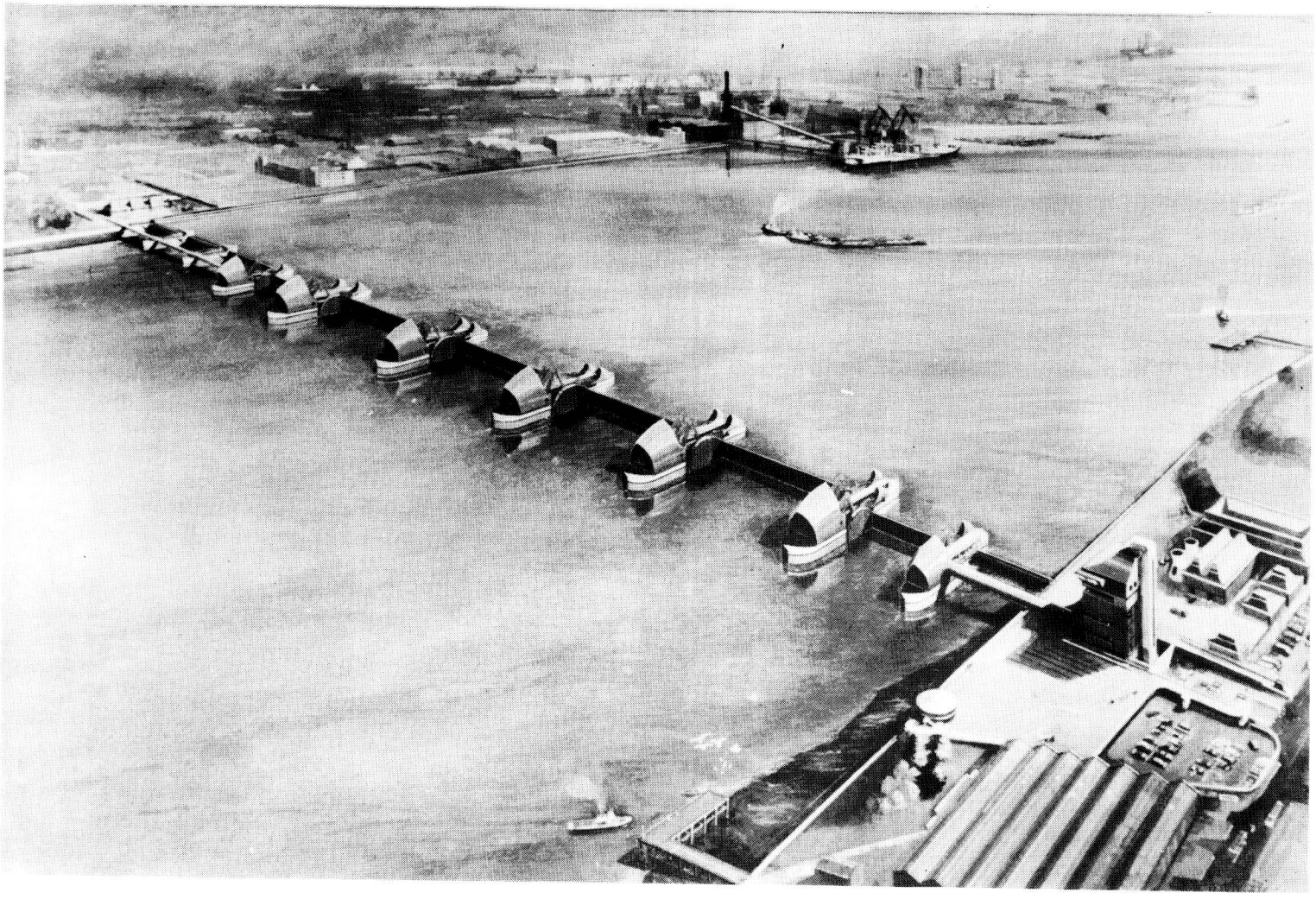
For these reasons, the reader will find some sections have changed little, whilst others have undergone some major revision. It is hoped that this new edition will continue to fill the needs of those requiring a book devoted to the theory and practice of civil engineering drawing.

Robert B Matkin
1982

Part One Drawing

Chapter 1 Equipment

Model of the Thames Barrier as it will appear on completion. (Photograph supplied by the Greater London Council)



1.1 THE MECHANICS OF ENGINEERING DRAWING

Engineering drawings are based upon a pair of axes, x and y, at right angles to each other, but not necessarily parallel to the edges of the drawing surface. The simplest way of providing these axes is by a square or parallel rule and set squares on a drawing board, Fig. 1.1.

It is convenient to have the most frequently used fixed angles on the set squares and two will be required with angles of 90°/45° and 90°/60°/30°.

The choice and quality of instruments is an individual one and generally gained through usage and experience, each person having likes and dislikes of any particular 'model'. The best advice that can be given is not to buy cheap goods but to choose your equipment with care, examining carefully the construction and quality and, rejecting anything which shows indifferent workmanship. (See, for example, that there are no rough edges to set squares or rules.) Drawing instruments, like most other things, offer better quality the more you pay. But quality, no matter how good, will not produce better quality drawings unless the person using them is professionally competent.

It is not advisable to start by purchasing sets of equipment, buying individual items means you can shop around to get the most suitable items from a varied selection of manufacturers.

Always remember one thing, drawing equipment is generally something you buy only once in your life, so obtain the quality of goods that will last.

1.2 DRAWING INSTRUMENTS AND OTHER EQUIPMENT

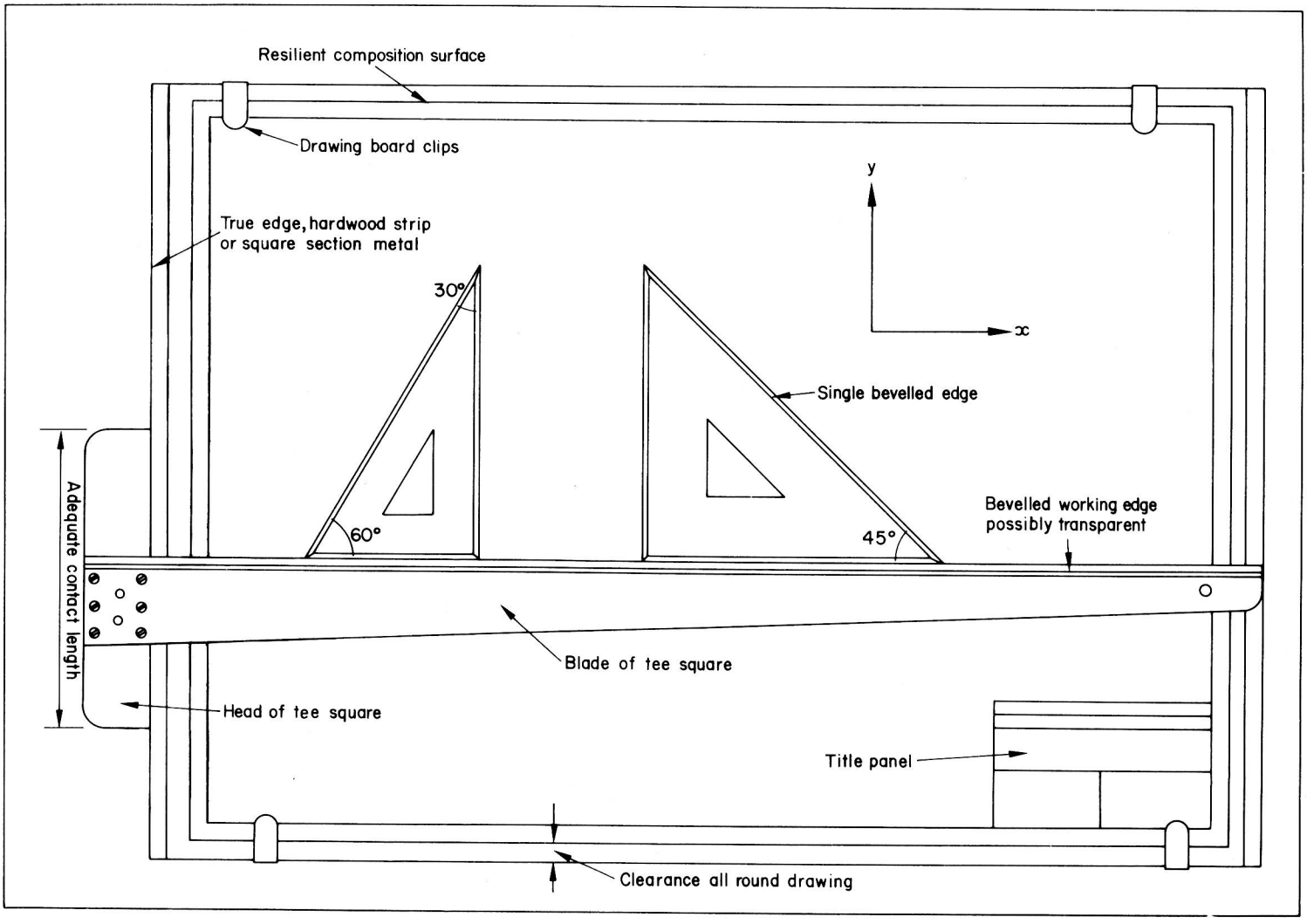
There are three main headings in this section:

(a) personal drawing equipment and its use
(b) materials on which drawings are made
(c) methods of supporting the drawing materials.

(a) Personal drawing equipment

Some of the essential items of personal equipment that are required by a student comprise:

(a) set squares
(b) scale rule
(c) compass or beam compass
(d) springbow compass
(e) pencils
(f) eraser
(g) erasing shield
(h) sandpaper block
(j) protractor
(k) drawing board clips
(l) duster.



1.1 Drawing board ready for use with paper held in place by clips.

(As the letter i, especially as a capital, can be confused with the number one or the letter l particularly in freehand writing, it should not be used as a reference.)

A smaller list of equipment includes some items that will be found useful at a later stage:

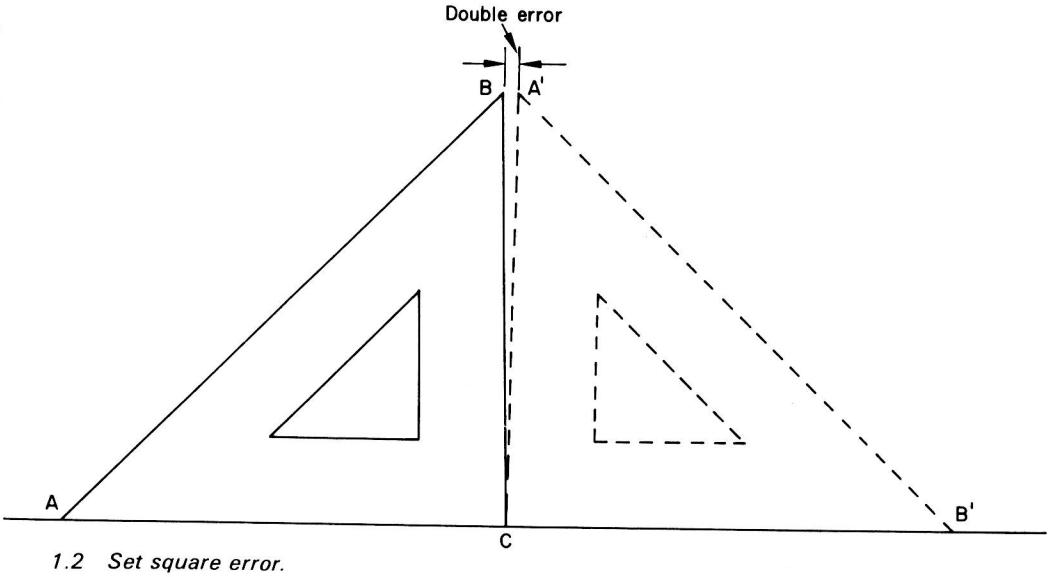
(m) adjustable set square
(n) french curves and flexible curve
(o) pens.

A brief description of these items follows with some notes on their use.

Set squares. As the name implies these are squares with set or fixed angles. They are generally made of plastic and of two types, the 45° and 60°/30°. A reasonable size set square measures about 250 to 300 mm on the long side. It is advisable to have them with the edges bevelled on one face only. With the bevelled edge uppermost, accurate pencil work can be done, whilst ink can be used when the bevel is underneath. In this way there is little fear of blots or smudges.

The accuracy of the right angle can be checked as shown in Fig. 1.2 by swinging the set square from the dotted to the full-line position on a straight edge about the point C. A line drawn along the edge BC each time will indicate the double error. Fig. 1.3 shows how a perpendicular can be drawn using two set squares.

When moving set squares about the drawing always lift them before changing the position, otherwise dirt or dust on the drawing will cause smudges and give the drawing an untidy appearance.



1.2 Set square error.

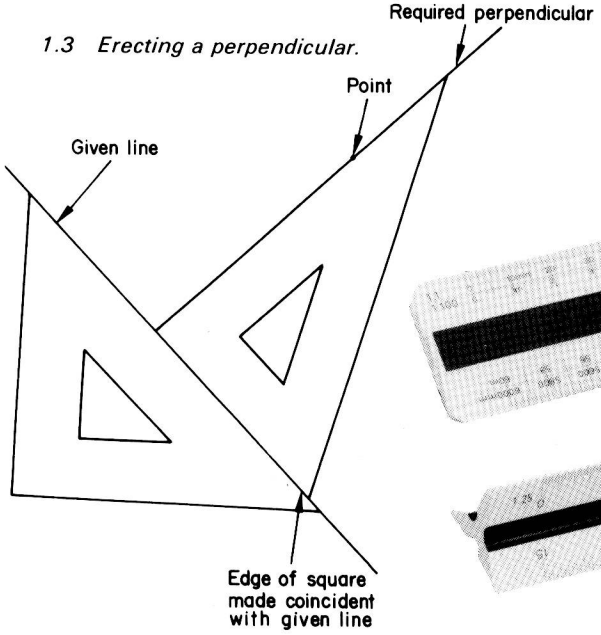
Scale (Fig. 1.4). The term scale in drawing can mean two things, it can be the scale of a drawing, see Chapter 3, or the instrument used to measure distances on a drawing.

There are several varieties of scale manufactured, but the most favoured are those with either an oval cross section (Fig. 1.4 (a)) or of triangular construction (Fig. 1.4 (b)). Each side of the scale carries a different scale ratio and these vary according to the type of work they are to be used for. They should have plastic edges.

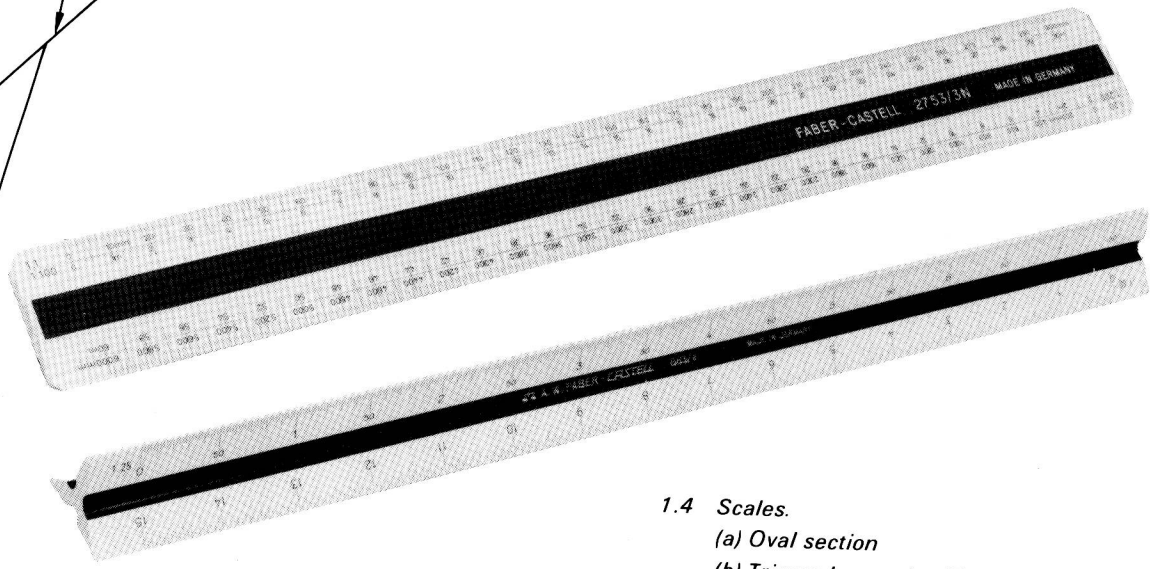
On an oval scale four different scale ratios can be engraved whilst on the triangular model this goes up to six scale ratios, even these are increased on some models by doubling up the number of scales per edge, i.e. 1:10 and 1:100 being engraved together. The scales suitable for the student are 1:2.5, 1:5, 1:10, 1:20.

Never use the scale for ruling lines or slitting paper. Always use the right scale ratio and do not convert from a different ratio. Never use the scale to set compass radii or divider distances, always mark the required distance on a piece of paper and use these marks for the setting.

Compass or beam compass (Fig. 1.5). These are used to draw circles of radii over about 40 mm, the beam compass with its extension bar can draw much larger circles. The compass point is usually reversible, one point being shouldered to prevent it making a large hole in the paper should a number of circles have to be drawn from the same centre.



1.3 Erecting a perpendicular.



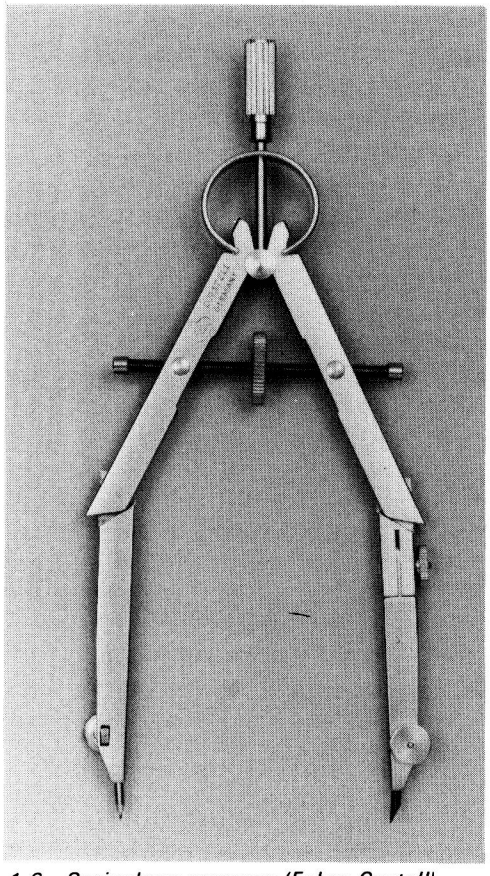
1.4 Scales.
(a) Oval section
(b) Triangular section (Faber-Castell).

A beam compass can either be a separate instrument on its own or in the form of an extension bar fitted to a compass or large springbow compass. Either way the purpose is to extend the size of radii that can be drawn. For large radii the beam compass is more accurate than an ordinary compass opened wide, because with the former there is no tendency for the arms to splay out when pressure is applied to the lead point.

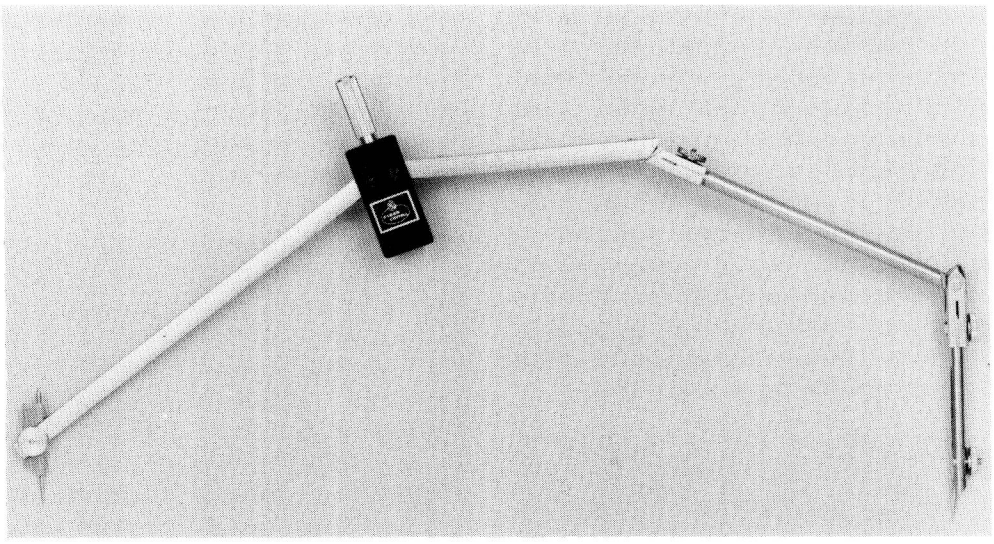
Springbow compass (Fig. 1.6). Small radii up to about 40 mm are drawn using this instrument, although there are springbows which will open up to give radii much greater than this but conversely will not close down to draw the very small radii.

They can be set very accurately to a given radius by means of the small knurled wheel set between the compass legs.

On all compasses both the leads and points are replaceable. All leads should be sharpened on one side only.



1.6 Springbow compass (Faber-Castell).



1.5 Large compass (Faber-Castell).

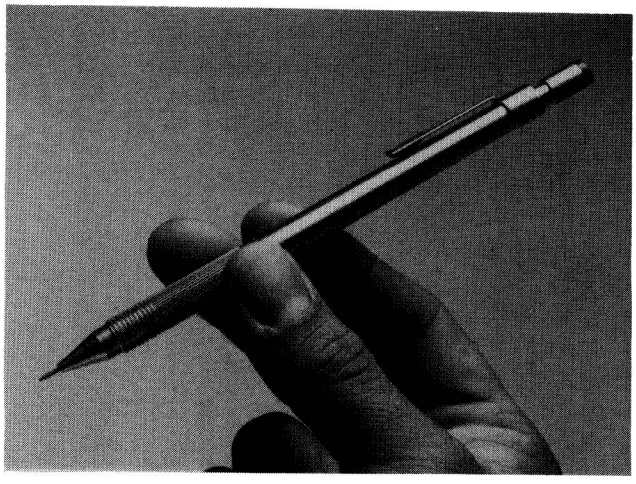
Pencils (1.7). Practically all drawings are made with a pencil even if at a later stage they are to be finished in ink.

There is a wide range of hardness of lead available and these are graded, B for soft leads and H for hard leads, an HB grade coming in the centre of the range. Pencils used on translucent material are generally of grade 2H for linework and F grade (between HB and H) for lettering. When using opaque paper, the most suitable grades are H or 2H for linework and HB or F for lettering, a lot depending on how heavy handed is the operator. Construction lines in all cases are best drawn with a pencil grade of not less than 3H.

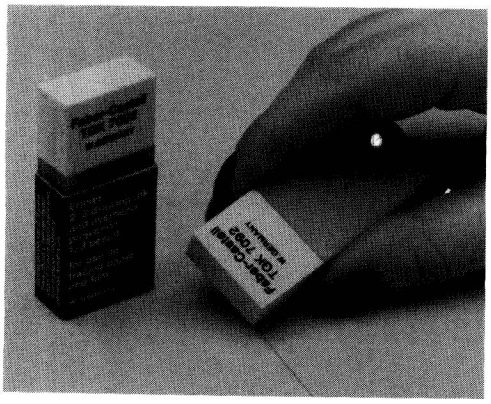
There are wood-cased pencils, a mechanical type which grips the lead and fine lead holders. The first type requires the wood and lead to be constantly sharpened by means of a knife, not in a pencil sharpener. The second type has a piece of lead held in a mechanical clutch which can be quickly released to allow the lead to be changed or resharpened. Both of these types require the lead to be sharpened either to a conical point for lettering and sketching or to a chisel point for line drawing, the chisel form does not require sharpening as often as the conical one. Compass leads are sharpened on one side only – that which is remote from the point.

The third type, the fine lead holder (Fig. 1.7), does not need sharpening, a constant width of line is achieved by using a pencil with the appropriate lead diameter. The holder illustrated has an automatic lead feed, the push button being used only when a new lead is to be injected into the fine tube.

1.7 TK fine lead holder (Faber-Castell).



Eraser (Fig. 1.8). Pencil marks can be removed from most papers by using a good quality eraser without damaging the surface. Ink work will need a harder eraser and damage may be caused to the working surface depending on the type of drawing material being used. Ink marks on plastic film can be removed by scratching them out using a sharp knife or razor blade, but care must be taken to do this lightly otherwise holes will appear. Ink work on ordinary opaque drawing paper can be obliterated using 'Snopake'. When it has dried lines can be drawn over the painted area.

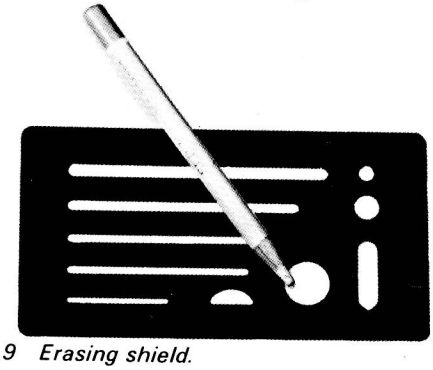


1.8 Eraser for ink and pencil (Faber-Castell).

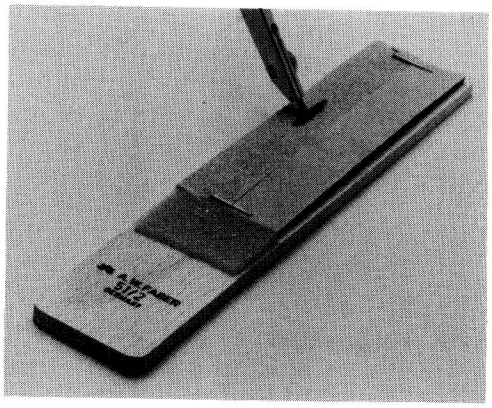
Art gum blocks are very useful for cleaning up unwanted construction lines on finished drawings, they do however make a lot of crumbs.

Erasing shield (Fig. 1.9). If the work of the eraser is to be over a restricted area, particularly where there are numerous other lines, an erasing shield of thin metal or plastic can be used. An appropriate slot is placed over the portion to be removed thus preventing the eraser from removing adjacent linework.

Hard pencils can form a groove in the paper and it is difficult sometimes to remove the lead deposited at the bottom of this groove. This can be overcome to some extent by placing a piece of hard material, such as a set square, under the drawing paper beneath the line to be removed and then using the eraser and shield the groove will be ironed out allowing the lead deposit to be rubbed out.

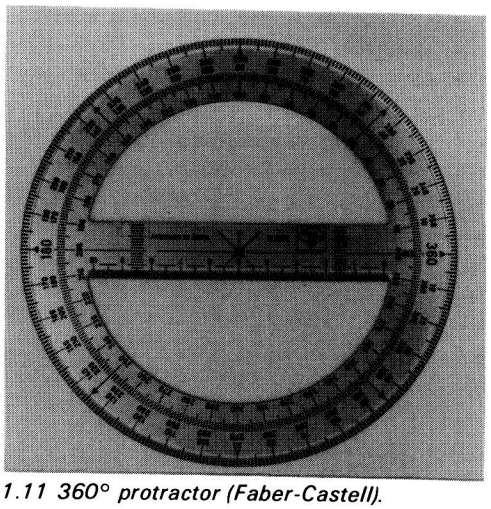


1.9 Erasing shield.



1.10 Sandpaper block (Faber-Castell).

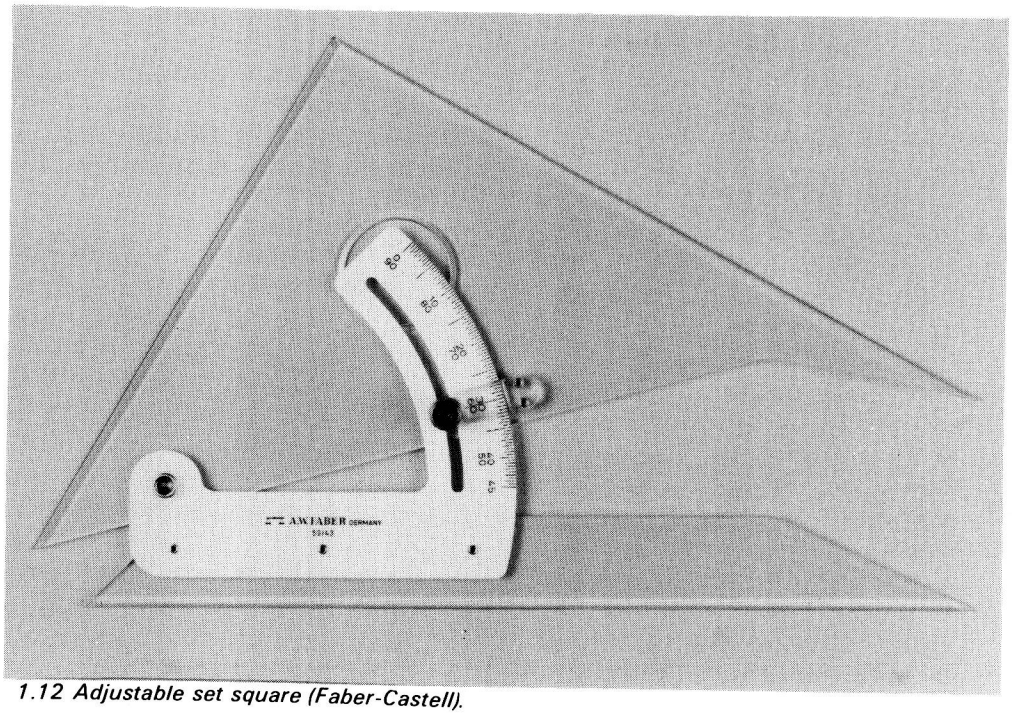
Sandpaper block (Fig. 1.10). It has been seen that pencil and compass points need to be sharpened to a conical or chisel point at frequent intervals. This can be done using a very fine sandpaper block or well-worn metal file. Remember, sharpening in this way causes a lot of lead dust and this should be removed by knocking block or file into the wastepaper bin each time it is used.



1.11 360° protractor (Faber-Castell).

Protractor (Fig. 1.11). Survey drawings frequently require angles to be set out to a lower degree of accuracy and this can be done by means of a protractor. There are two types, the half circle and the full 360°. The latter will be found to be more useful.

Drawing board clips. The drawing material is fixed to the drawing surface by means of spring clips or, if the drawing paper does not reach the limits of the board, by draughting tape. Drawing pins are *not* used as their continual use marks the drawing surface.



1.12 Adjustable set square (Faber-Castell).

Duster. It might seem strange to include a duster amongst drawing equipment, but it is a most essential part of the draughting profession. The drawing medium, tee square, set squares and all other equipment, including the pencil point after sharpening, must at all times be kept free of dust and eraser dirt. This is achieved by regularly wiping everything, hands included, with a clean duster or stockinette.

The remaining three items will be found useful at all stages of drawing office work and in the graphics to be done for other subjects in an engineering course.

Adjustable set square (Fig. 1.12). As the name implies, this square has an adjustable arm allowing the square to be set to an angle from 0° to 90°. With this square, the ordinary 45° set square can be dispensed with, but not the 30°/60° version. When set at this latter angle, the leg of the adjustable is not long enough.

French curves and flexible curve (Fig. 1.13). Two fundamental faults ruin a drawing – bad printing and badly drawn irregular curves. Smooth irregular curves can only be produced with the aid of a French curve or a flexible curve. A set of French curves consists of several shapes, bits of ellipses, parabolae and hyperbolae. The curves are made of wood or plastic, sometimes bevelled on one edge for ink use. The curve is moved round until one part fits the required shape, the curve, or one of the others in the set, may have to be moved about to complete an irregular shape.

The flexible curve can be shaped for a length of an irregular curve and it will retain its bent shape. Its disadvantage is that previous bends cannot always be completely removed.

1.13 Drawing irregular curved lines.
(a) French curves (Jakar)
(b) Flexible curve (Jakar-flex).

Pens (Fig. 1.14). It is sometimes necessary to finish a drawing in ink, particularly in the case of illustrations or drawings forming documents for tenders or public enquiries, etc. General drawing office work uses ink far less these days than it used to because printing machines have now reached a very high standard of reproduction from pencil work.

Ink drawing is not easy and requires a lot of practice to reach an acceptable standard. Modern equipment in the form of technical drawing pens has helped considerably in this respect.

There are several technical pens manufactured but all revolve around a similar basic function. That is, there is a holder containing

1.14 Technical drawing pen – Marsmatic 700.
(Staedtler U.K. Ltd)

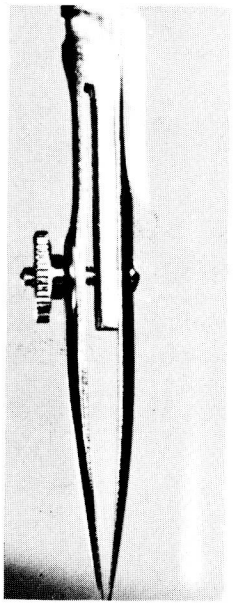
drawing ink or a cartridge of ink which feeds the fluid to a fine tubular drawing point, permitting lines of equal thickness to be drawn. The nib units can be removed thus allowing a whole series of other nibs of different thickness to be used. Pens having nib sizes from 0.13 mm to 2.0 mm can be obtained. Compass attachments are also available for use with these pens.

A suitable set of pen sizes for general drawing use is:

0.35 mm for centre lines, dimensions and note leaders
0.5 mm for hidden edges
0.7 mm for visible edges.

Lettering, see also Chapter 3, can be done using these pens and suitable stencils, and there are also special stencils for a variety of everyday shapes which can be used with pen or pencil.

The old-type drawing pen (Fig. 1.15) is still available but it is less easy to operate in inexperienced hands.



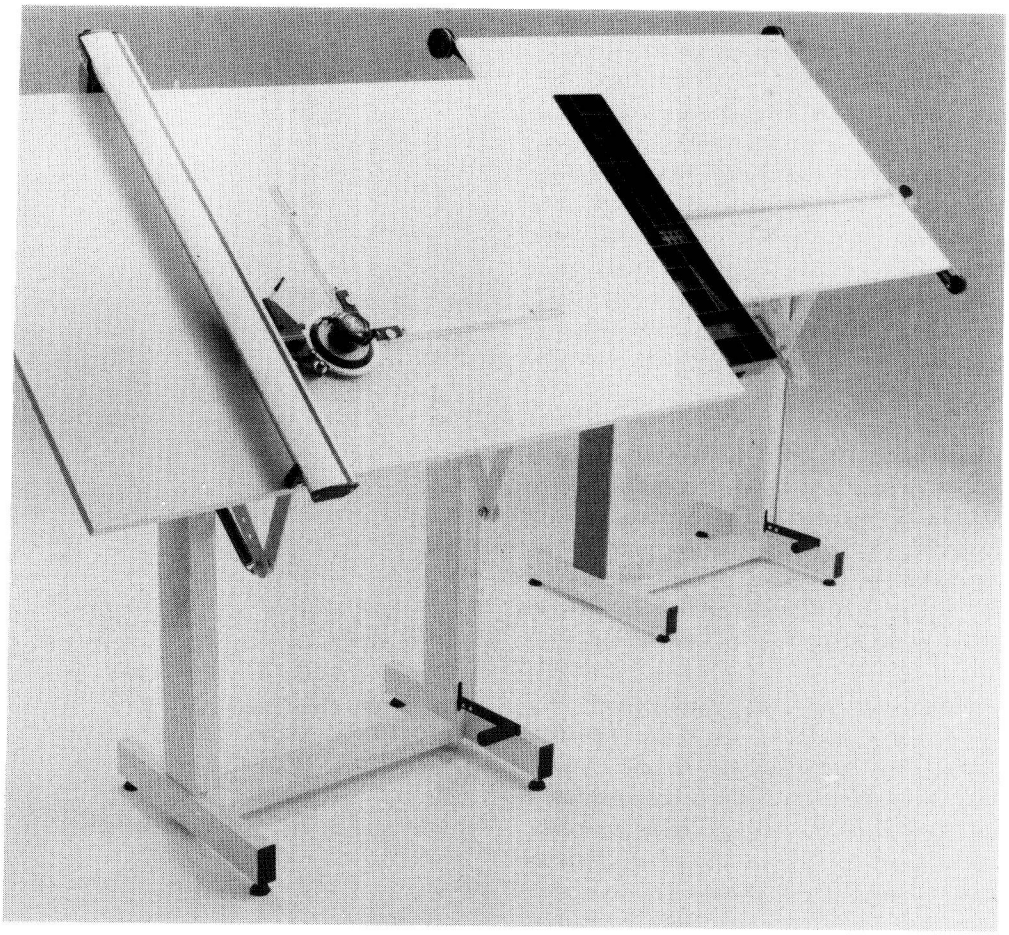
1.15 Drawing pen.

(b) Materials on which drawings are made

Drawings can be made on paper and film, the latter being the most acceptable for ink work. At one time all ink work was done on linen cloth but the more stable plastic film has now taken over, being cheaper and easier to manipulate.

A reasonable quality cartridge paper will meet most student needs. It should have a surface that is smooth enough to take ink and yet strong enough to resist rubbing out. Detail paper is a thin, but strong, semi-transparent paper with a tough, smooth surface. It is used professionally for sketching out schemes in the design stage.

Tracing paper provides a tough, very smooth, working surface and will withstand plenty of rubbing out of pencil lines. It is more transparent than detail paper and will produce good dyeline prints, see Chapter 9, provided the pencil work is fairly dense. The best prints are obtained from drawings finished in ink.

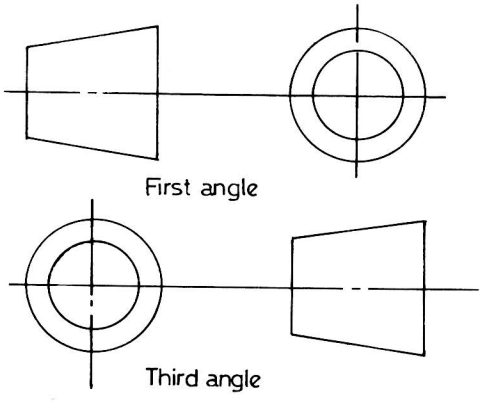


1.16 Left: Stand with medium draughting machine.
Right: Stand with parallel motion straight edge. (Supplied by Utopia Drawing Office Equipment Ltd)

(c) Methods of supporting the drawing materials (Fig. 1.16)

The drawing medium, paper, film, etc., must at all times be supported on a flat surface which is stable. There are two categories for this:

(a) drawing board
(b) draughting machine.



1.17 BS symbols showing method of projection.

Drawing board (see Fig. 1.1). Drawing boards should preferably be battened and have a hard inset let into the working edge, along which the tee square slides if one is being used. There is a wide range of quality in boards, the cheap ones are made of plywood and suitable only for the lowest grade of work. Whilst most drawing offices in educational establishments provide boards for student use, it is desirable that a personal one is obtained. All work cannot be done away from home and, as has been mentioned already, practice is the only way to perfection.

Boards come in sizes slightly larger than the corresponding A size of paper that is to be used. In professional drawing offices boards of A0 size will be used but for the average student need an A1 size will be sufficient. For a sloped work surface raise board on a block.

Unless the board is to be equipped with some form of draughting machine, it will be necessary to use a tee square. This should be well constructed, the stock and the blade being well joined. The blade must be as long as the board and have the drawing edge bevelled. The stock must not be too short for when it is held against the board there must be no movement in the blade itself. Vertical lines are drawn by resting a set square along the blade, blade and set square being held firmly with one hand whilst the vertical line is drawn. When not in use, tee squares should be hung up using the hole provided in the blade.

A plain wood drawing board will need a backing sheet of paper beneath the drawing. This protects the surface of the board from the use of a hard pencil and also gives some resilience which is necessary when drawing.

Draughting machines (Fig. 1.16). Fundamentally they consist of a drawing board supported on a stand, which is adjustable both for height and inclination. The axes of the drawing can be provided by:

(a) a parallel motion straight edge and set squares
(b) a pantograph arm, or other system, with a drawing head.

The parallel motion type provides a straight edge that moves smoothly up and down the board, controlled possibly by wires. Set squares and adjustable squares are used in the same way as with a tee square. Not having to keep the straight edge firmly in place means there is an increase in drawing speed.

Machines with a drawing head dispense with the use of set squares. They have two scales, which are interchangeable with different scale ratios, that are set at a right angle and the head can be rotated to any angle where it can be clamped. Some heads operate on a pantograph arm whilst others have a vertical and horizontal sliding system. A desired angle for the head is set by moving a part-graduated circle of degrees against a fixed mark or, as in a modern version, the angle is set from a digital protractor head with a liquid crystal display reading 5 minutes of arc.

1.3 FIRST STEPS IN DRAWING

The steps outlined below, whilst being simple, do, nevertheless, speed the work of preparing drawings.

(a) Attach paper to board with clips, using a backing sheet of paper if necessary. If the paper is too small to fill the board, draughting tape should be used.
(b) If paper is kept rolled up in a tube, see that it is done with the working face outwards, it will then be easier to control when fixed to the board.
(c) Complete the title block and draw a border to the paper if required.
(d) Observe the following procedure when making a drawing as it will provide a methodical approach, at the same time retaining neatness and accuracy with increased speed.
(i) Decide the arrangement on the paper of all the views required, spacing them out intelligently.
(ii) Insert the main centre or datum lines in all the views.
(iii) Draw in the required views lightly, building up the drawing from the centre or datum lines. Do not attempt to complete one view before moving to the next but build up parts of the object in all the views. Construction and projection lines should therefore be carried to other views wherever possible.
(iv) Clean up and check the drawing removing unwanted construction and projection lines.
(v) Line in circles and arcs before the straight lines, it is easier to connect a straight line to an arc than the other way round.
(vi) Complete the lining in and again if this is done methodically (vertical lines, then horizontal lines and finally sloping lines) the drawing will be done that much quicker.
(vii) Insert dimensions and any notes.
(viii) Add section lines, titles and scale noting the type of projection used. On this latter point, at one time the type of projection used was spelled out, now the BS symbol is used (see Fig. 1.17).
(ix) At all times keep the pencil point sharp and make sure the instruments and paper are constantly wiped, removing dirt or rubber crumbs with a duster. You will find also that hands tend to collect dirt and should be washed quite frequently.
(x) Throughout the book reference will be made to BS 308, *Engineering Drawing Practice* – Parts 1, 2 and 3. This is the full standard relating to engineering drawing and it is an expensive publication. A condensed, and cheaper version, has been produced, PD/7308 *Engineering Drawing Practice for Schools and Colleges*. This introduces the students of technical drawing to the principles and conventions of BS 308.

1.4 ELEMENTARY DRAWING EXERCISES

These elementary drawing exercises are graded from straight line exercises through circular arcs to irregular curves needing French curves or flexible rulers.

The exercises are to test your precision, not your speed. Speed, which is important, can be gained later.

Make a complete drawing of the exercises, including a border and title panel with some printing and dimensions where appropriate. The newcomer to the drawing board can only gain confidence in the use of his equipment and learn his weaknesses, by plucking up the courage to attack the huge sheet of blank paper.

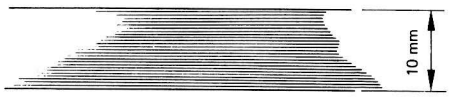
Use ink as soon as possible.

Use lines of different thickness and see the effect on the appearance of the drawing.

Perhaps the most revealing exercise is the 20 mm square subdivided into 2 mm squares. Lines irregularly spaced by only 0.1 mm will be all too obvious.

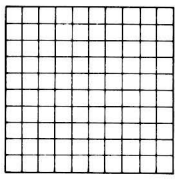
1. Straight line exercises

(a)



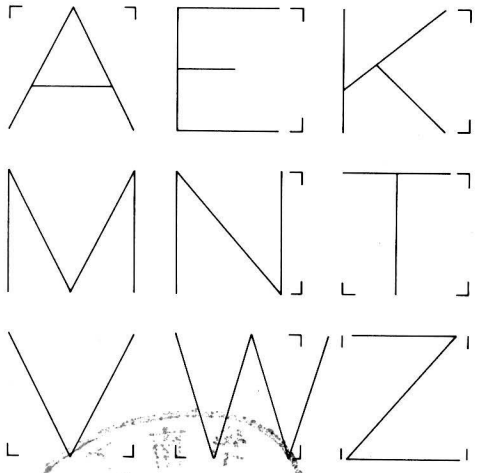
Draw as many distinct lines in 10 mm as possible

(b)



Draw a grid of 2 mm squares.

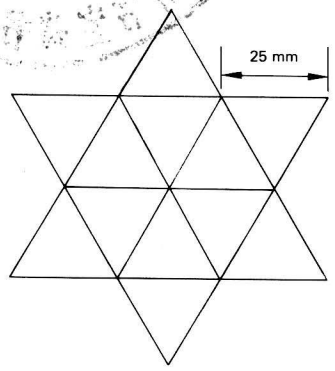
(c)



Construct these letters in 15 mm squares.

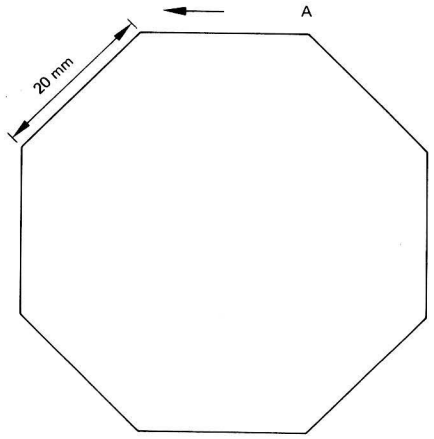
2. Set square exercises

(a)



Set out with a 'sixty thirty' set square and check the intersection of lines at the centre.

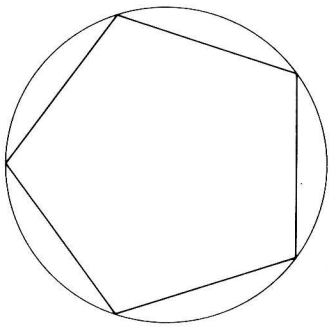
(b)



Start at A and go round the octagon setting out the sides in order, to see the error at A on completion.

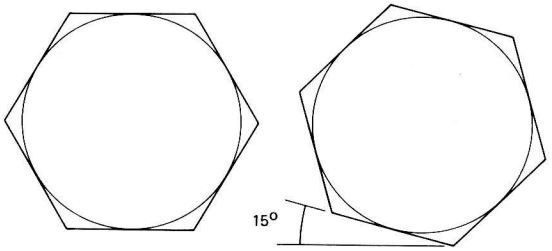
3. Compass and dividers exercises

(a)



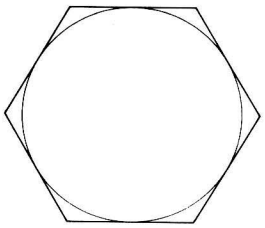
Pentagon in a circle of radius 25 mm
Divide the circumference by trial and error.

(b)



Draw a hexagon scribed round a circle of radius 25 mm

(c)



Draw a hexagon of sides 30 mm and inscribe a circle.