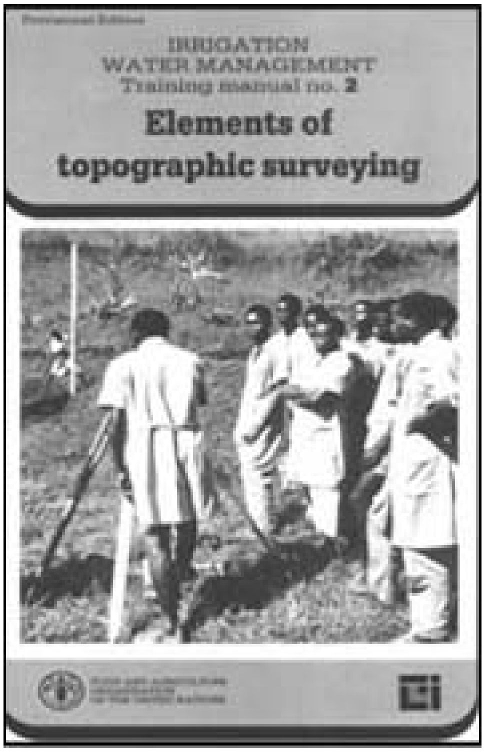
# Irrigation Water Management: Training Manual No. 2 - Elements of Topographic Surveying

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

a manual prepared jointly

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# PREFACE

This is one in a series of training manuals on subjects related to irrigation that will be issued in 1985 and 1986.

The papers are intended for use by field assistants in agricultural extension services and irrigation technicians at the village and district levels who want to increase their ability to deal with farm-level irrigation issues.

The papers contain material that is intended to provide support for irrigation training courses and to facilitate their conduct. Thus, taken together, they do not present a complete course in themselves, but instructors may find it helpful to use those papers or sections that are relevant to the specific irrigation conditions under discussion. The material may also be useful to individual students who want to review a particular subject without a teacher.

Following an introductory discussion of various aspects of irrigation in the first paper, subsequent subjects discussed will be:

- topographic surveying
- crop water needs
- irrigation scheduling
- irrigation methods
- irrigation system design
- land grading and levelling
- canals and structures
- drainage
- salinity
- irrigation management

At this stage, all the papers are marked provisional because experience with the preparation of irrigation training material for use at the village level is limited. After a trial period of a few years, when there has been time to evaluate the information and the use of methods outlined in the draft papers, a definitive version can then be issued.

For further information and any comments you may wish to make please write to:

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## ABOUT THIS PAPER

Elements of Topographic Surveying is the second in a series of training manuals on irrigation. This manual describes elementary surveying equipment and provides examples of their application. It thus guides field assistants and irrigation technicians in setting out straight lines, measuring distances, setting out right angles and perpendicular lines, calculating surface areas, setting out horizontal lines, slopes and contour lines and measuring differences in elevation.

# 1. ELEMENTARY SURVEYING EQUIPMENT



## 1.1 Chain and Tape

Chains or tapes are used to measure distances on the field.

A chain (see Fig. 1) is made up of connected steel segments, or links, which each measure 20 cm. Sometimes a special joint or a tally marker is attached every 5 metres. Usually, a chain has a total length of 20 metres, including one handle at each end.

**Fig. 1 A chain**

Measuring tapes (see Fig. 2) are made of steel, coated linen, or synthetic material. They are available in lengths of 20, 30 and 50 m. Centimetres, decimetres and metres are usually indicated on the tape.

**Fig. 2 A measuring tape**

## 1.2 Measuring Rod

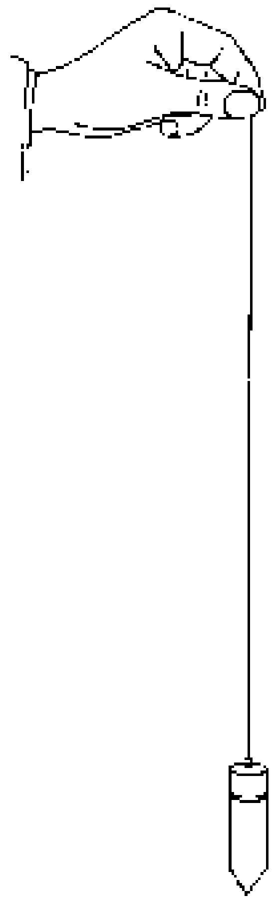
A measuring rod (see Fig. 3) is a straight lath with a length varying from 2 m to 5 m. The rod is usually marked in the same way as a measuring tape, indicating centimetres, decimetres and metres.

**Fig. 3 A measuring rod**

## 1.3 Plumb Bob

A plumb bob is used to check if objects are vertical. A plumb bob consists of a piece of metal (called a bob) pointing downwards, which is attached to a cord (see Fig. 4). When the plumb bob is hanging free and not moving, the cord is vertical.

**Fig. 4 A plumb bob**



# 1.4 Carpenter Level

A carpenter level is used to check if objects are horizontal or vertical. Within a carpenter level there are one or more curved glass tubes, called level tubes (see Fig. 5).

**Fig. 5 A carpenter level**

Each tube is sealed and partially filled with a liquid (water, oil or paraffin). The remaining space is air, visible as a bubble (see Fig. 6). On the glass tube there are two marks. Only when the carpenter level is horizontal (or vertical) is the air bubble exactly between these two marks (see Fig. 6).

**Fig. 6 Using a carpenter level**

# 1.5 Ranging Poles

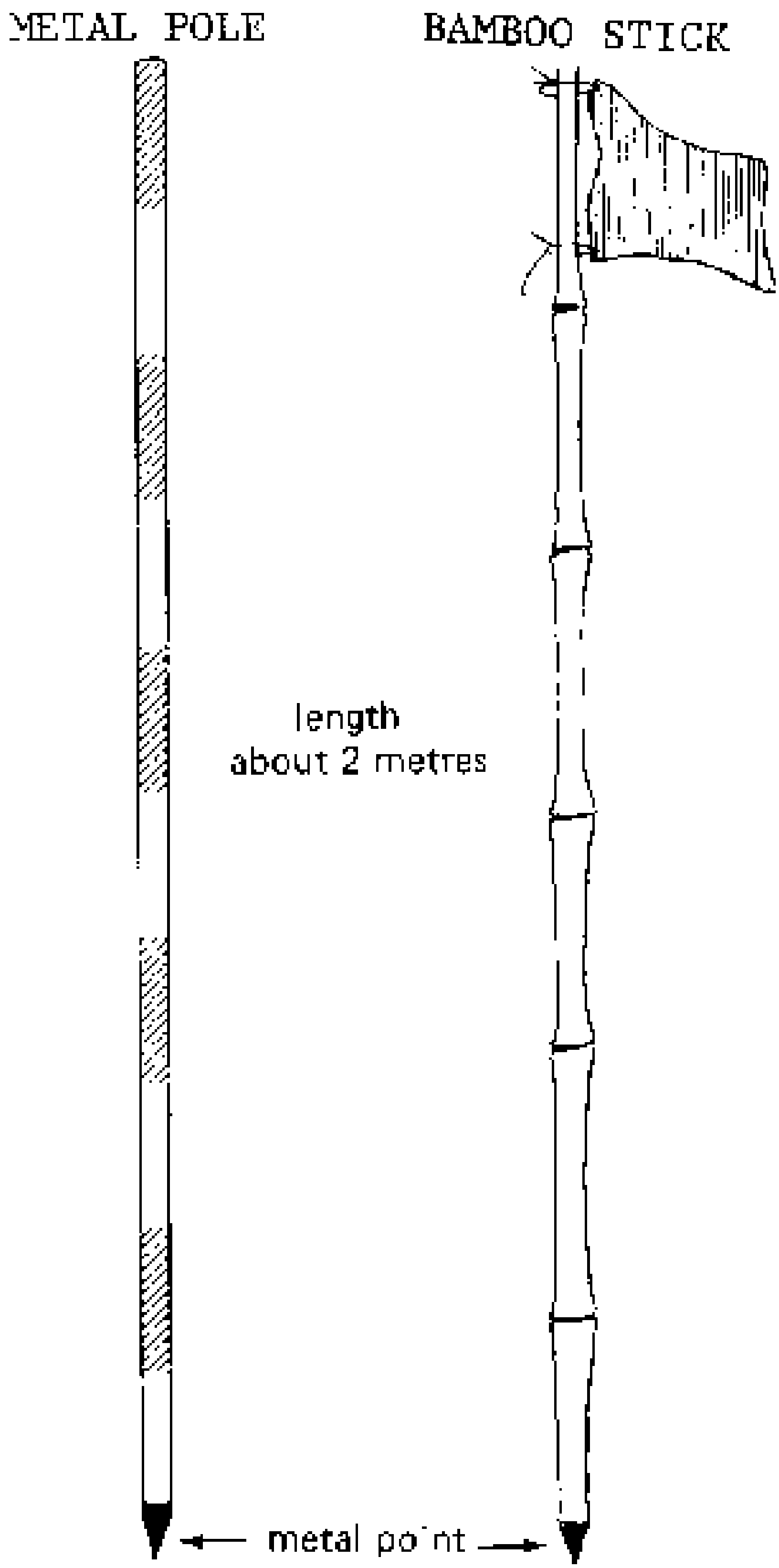
Ranging poles (see Fig. 7) are used to mark areas and to set out straight lines on the field. They are also used to mark points which must be seen from a distance, in which case a flag may be attached to improve the visibility.

Ranging poles are straight round stalks, 3 to 4 cm thick and about 2 m long. They are made of wood or metal. Ranging poles can also be home made from strong straight bamboo or tree branches.

REMEMBER: Ranging poles may never be curved.

Ranging poles are usually painted with alternate red-white or black-white bands. If possible, wooden ranging poles are reinforced at the bottom end by metal points.

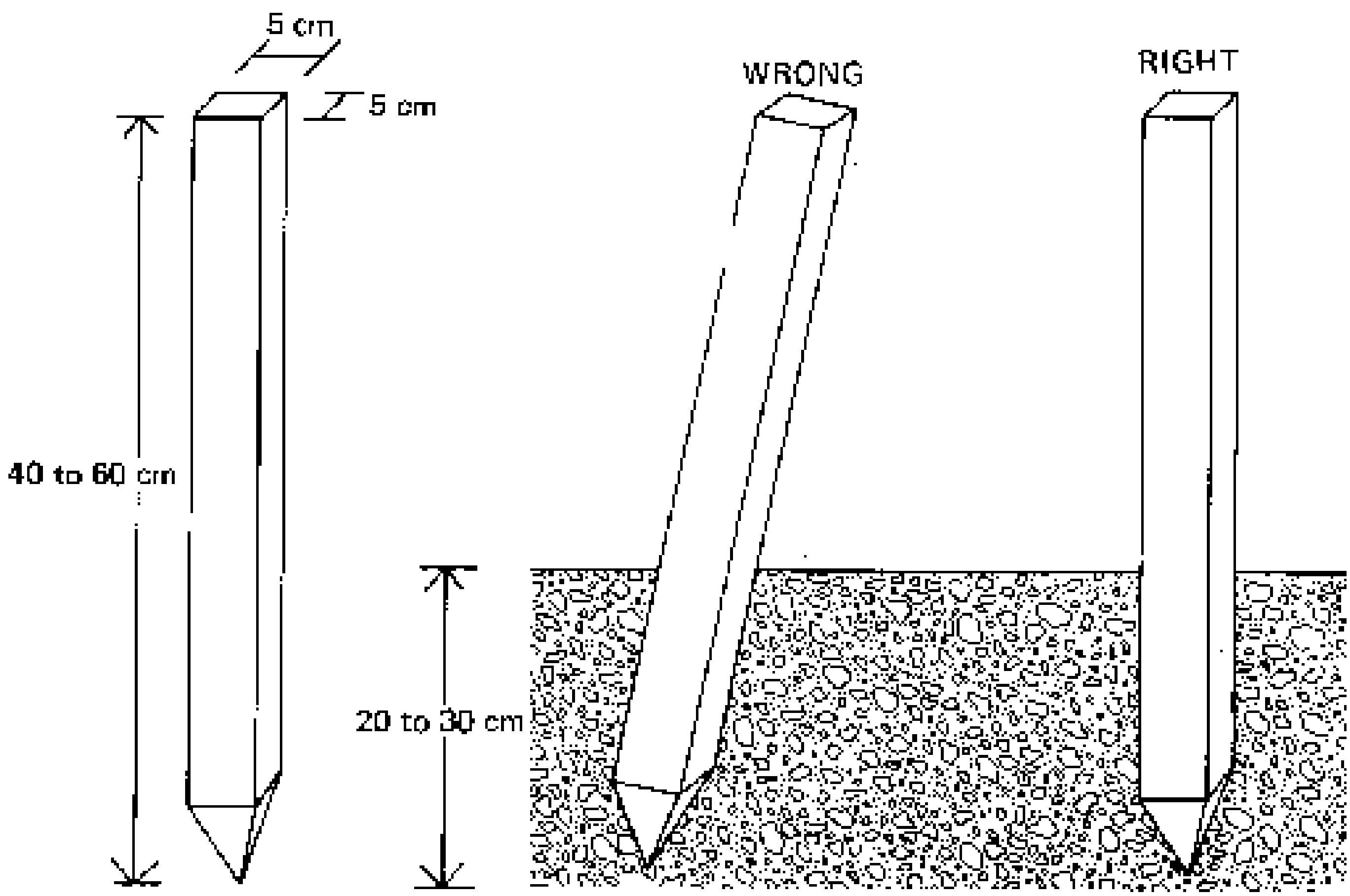
**Fig. 7 Ranging poles**



# 1.6 Pegs

Pegs (see Fig. 8) are used when certain points on the field require more permanent marking. Pegs are generally made of wood; sometimes pieces of tree-branches, properly sharpened, are good enough. The size of the pegs (40 to 60 cm) depends on the type of survey work they are used for and the type of soil they have to be driven in. The pegs should be driven vertically into the soil and the top should be clearly visible.

**Fig. 8 Pegs**



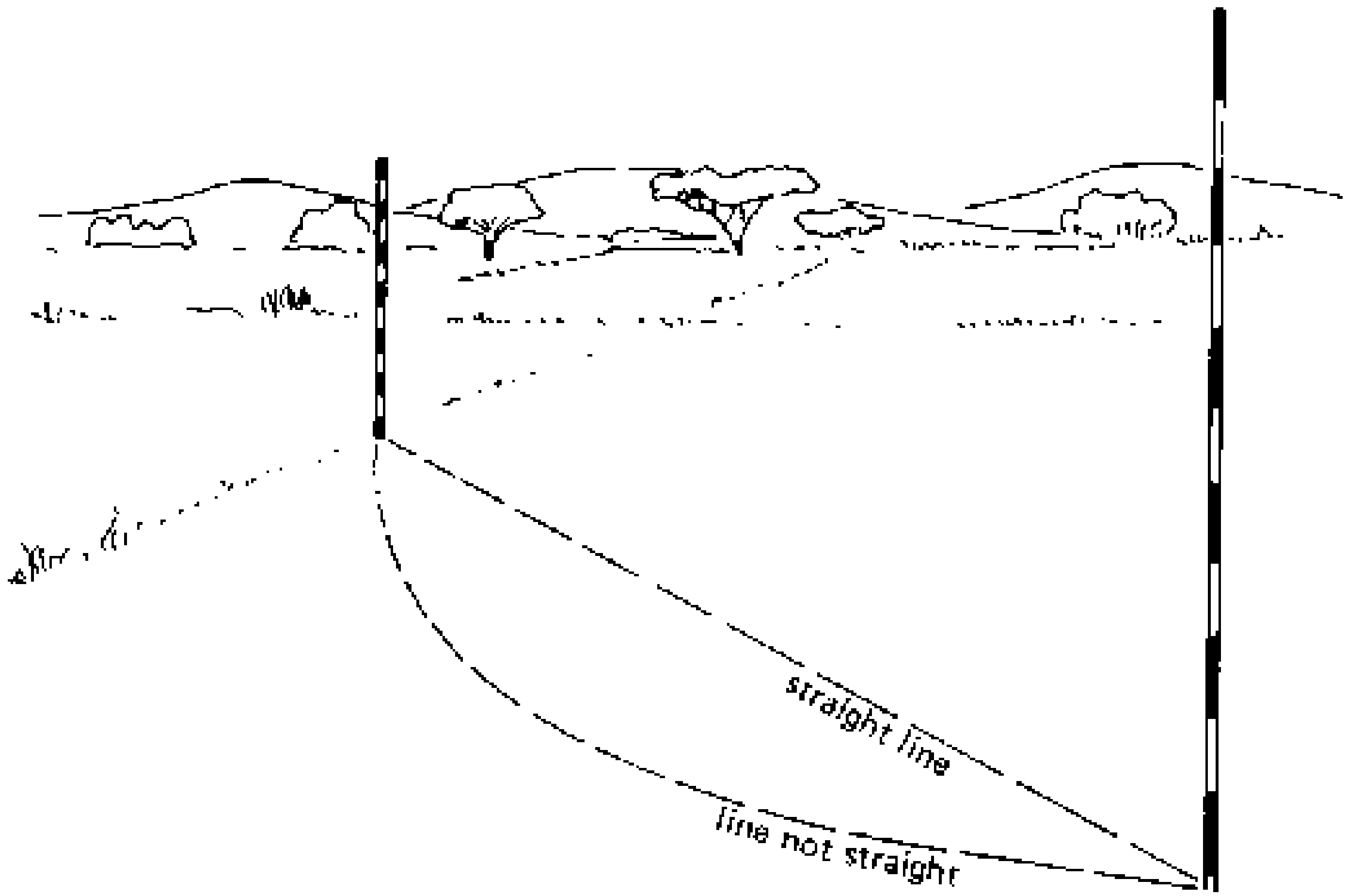
# 2. SETTING OUT STRAIGHT LINES



## 2.1 Definition of a Straight Line

A straight line is the shortest distance between two points on a map or between two points on the field (see Fig, 9).

**Fig. 9 A straight line**



# 2.2 Placing of Ranging Poles

The correct way to hold a ranging pole is to keep it loosely between thumb and index finger, about 10 cm above the soil (see Fig. 10).

When the observer indicates that the ranging pole is in the right position, the assistant loosens the pole. The sharp bottom point of the ranging pole leaves a mark on the soil exactly where the pole has to be placed. Once in place, it should be checked if the ranging pole is vertical, e.g. with a plumb bob, or a carpenter level (see Fig. 11).

**Fig. 10 Holding a ranging pole**

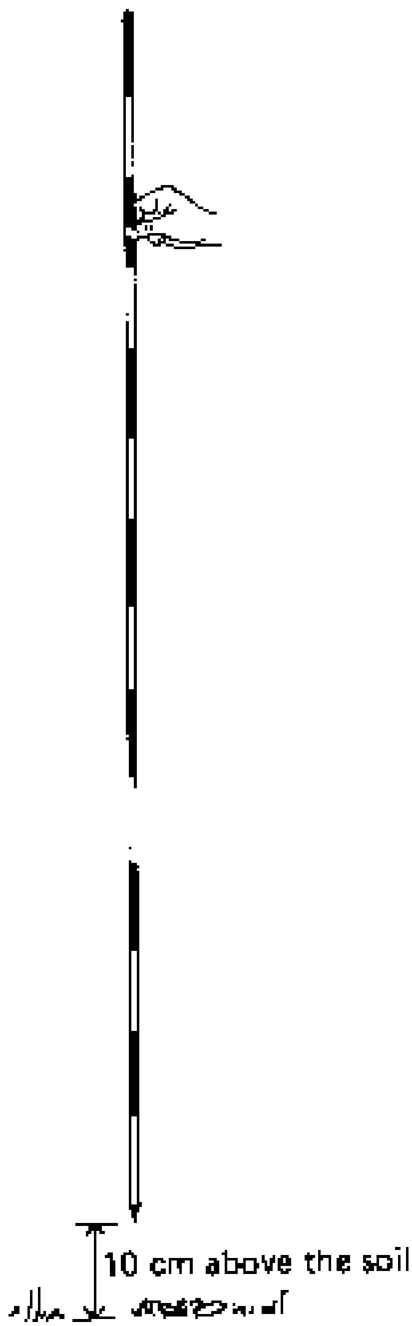
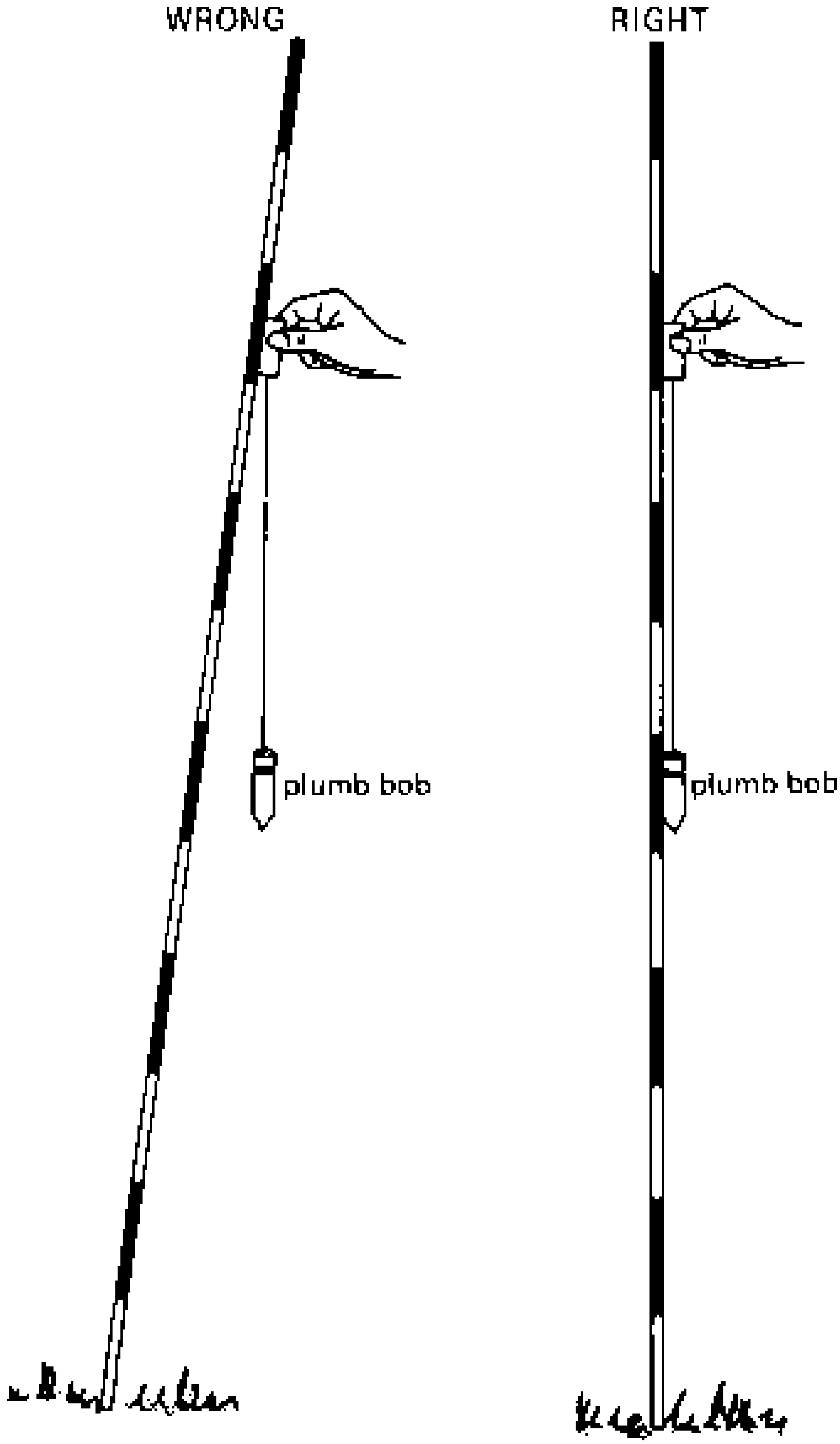



**Fig. 11 Placing a ranging pole**




# 2.3 Setting out Straight Lines

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This section indicates, step by step, how to set out straight lines over a short distance, over a long distance and over ridges or hills.

## 2.3.1 Setting out straight lines over a short distance

Step 1

As shown in Figure 12a, pole (B) is clearly visible for the observer standing close to pole (A). The observer stands 1 or 2 metres behind pole (A), closes one eye, places himself in such a position that pole (B) is completely hidden behind pole (A) (see Fig. 12a).

Step 2

The observer remains in the same position and any pole (C in Fig. 12b) placed by the assistant in between (A) and (B), which is hidden behind pole (A), is on the straight line connecting (A) and (B) (see Fig. 12b).

Step 3

The observer remains in the same position and any pole (D in Fig. 12c) placed behind (B), which is hidden behind poles (A), (B) and (C), is on the extension of the straight line connecting (A) and (B) (see Fig. 12c).

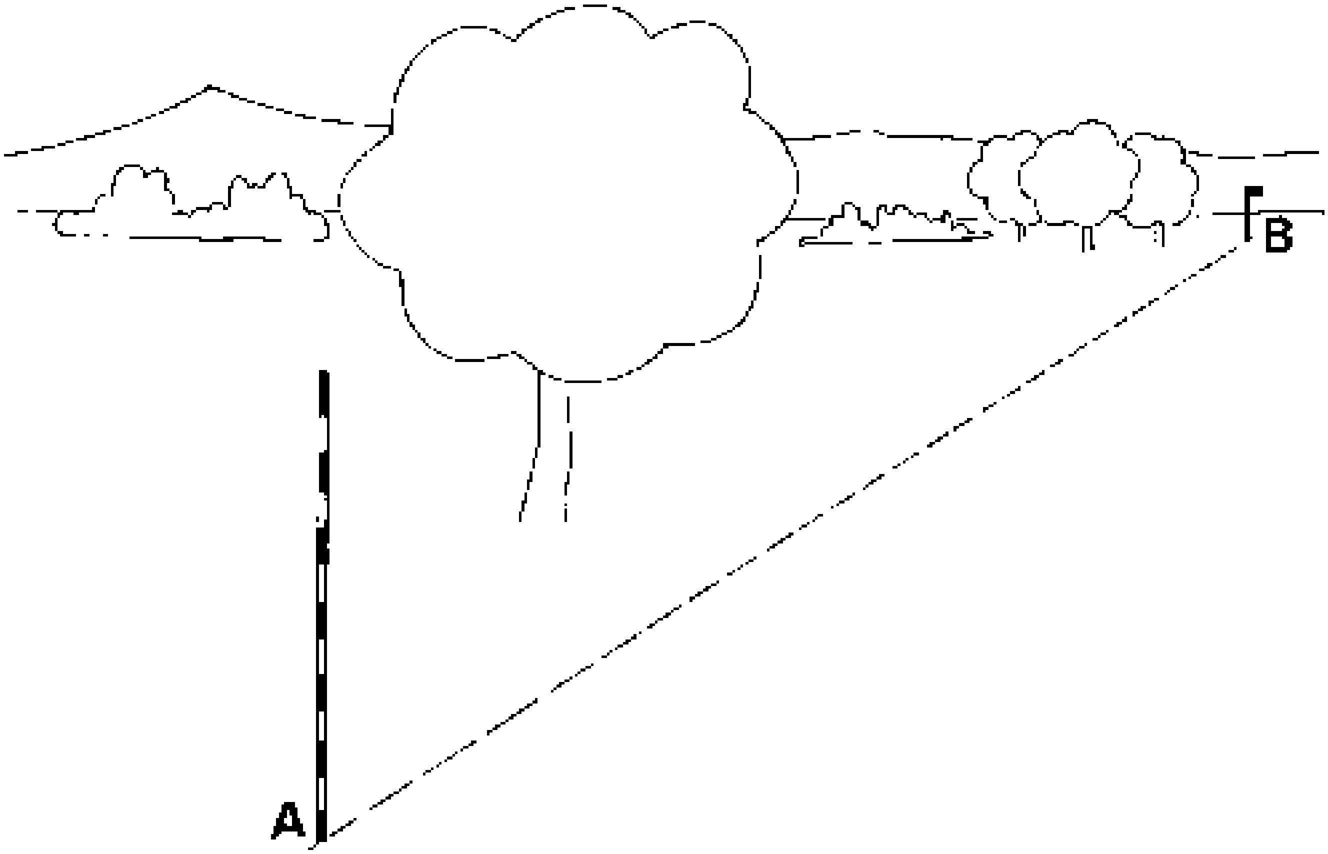
**Fig. 12 Setting out a straight line over a short distance**

In other words, poles (A), (B), (C) and (D) are in line if the observer, standing 1 or 2 metres behind pole (A), sees pole (A) only, while the other poles are hidden behind pole (A).

## 2.3.2 Setting out straight lines over a long distance

As shown in Fig. 13, ranging pole (B) is at quite a distance from pole (A) and it is hard to see pole (B) clearly. A flag is attached to ranging pole (B) to make it more visible.

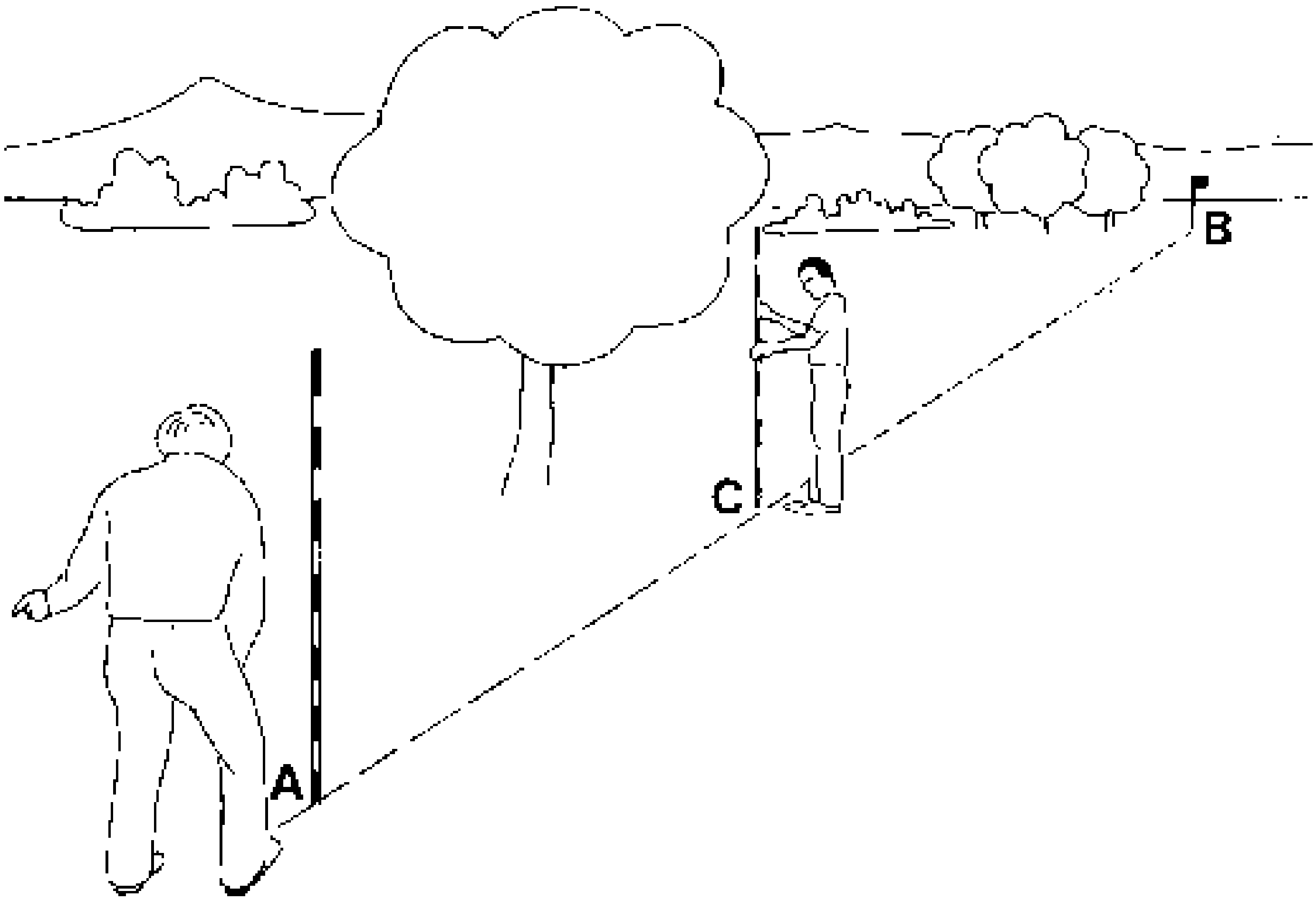
**Fig. 13 Setting out a straight line over a long distance**




Step 1

Pole (C) is approximately set in line with (A) and (B) at about one third of the distance between (A) and (B), closer to (A) (see Fig. 13a).

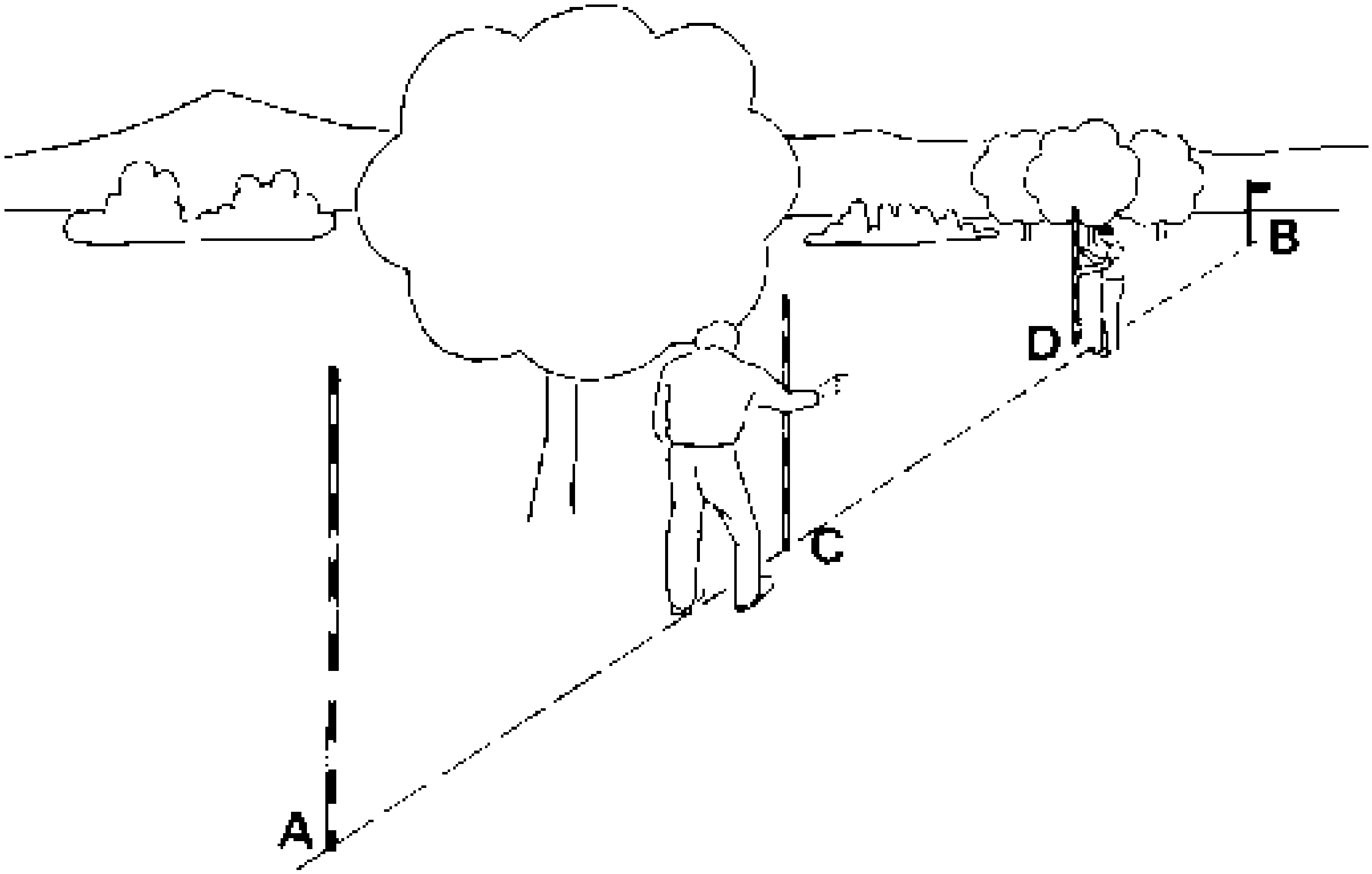
**Fig. 13a Setting out a straight line over a long distance, Step 1**




Step 2

The observer moves to pole (C) and pole (D) is set in line with (C) and (B) (see Fig. 13b).

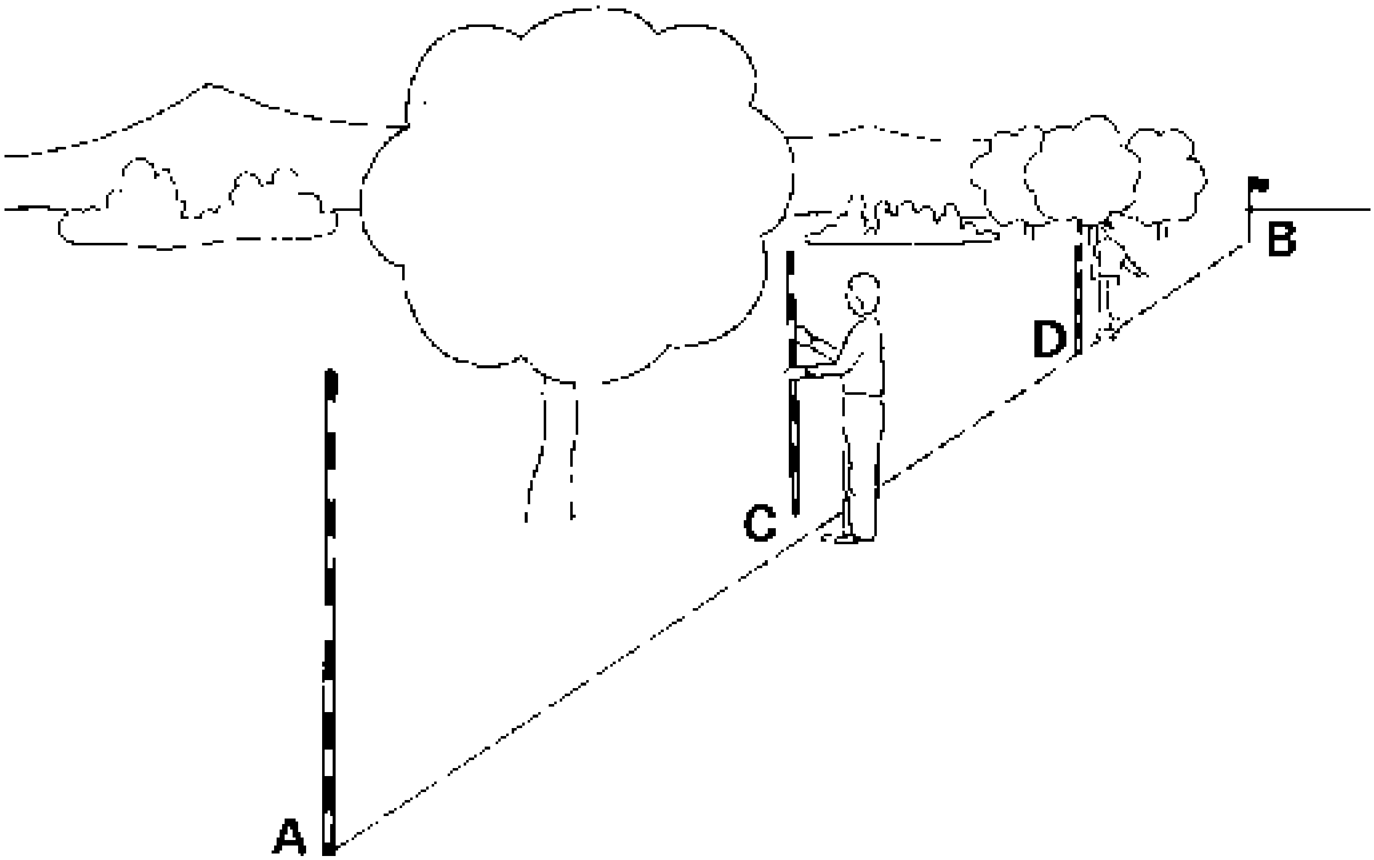
**Fig. 13b Setting out a straight line over a long distance, Step 2**




Step 3

The observer moves Co pole (D) and pole (C) is reset in line with (D) and (A) (see Fig. 13c).

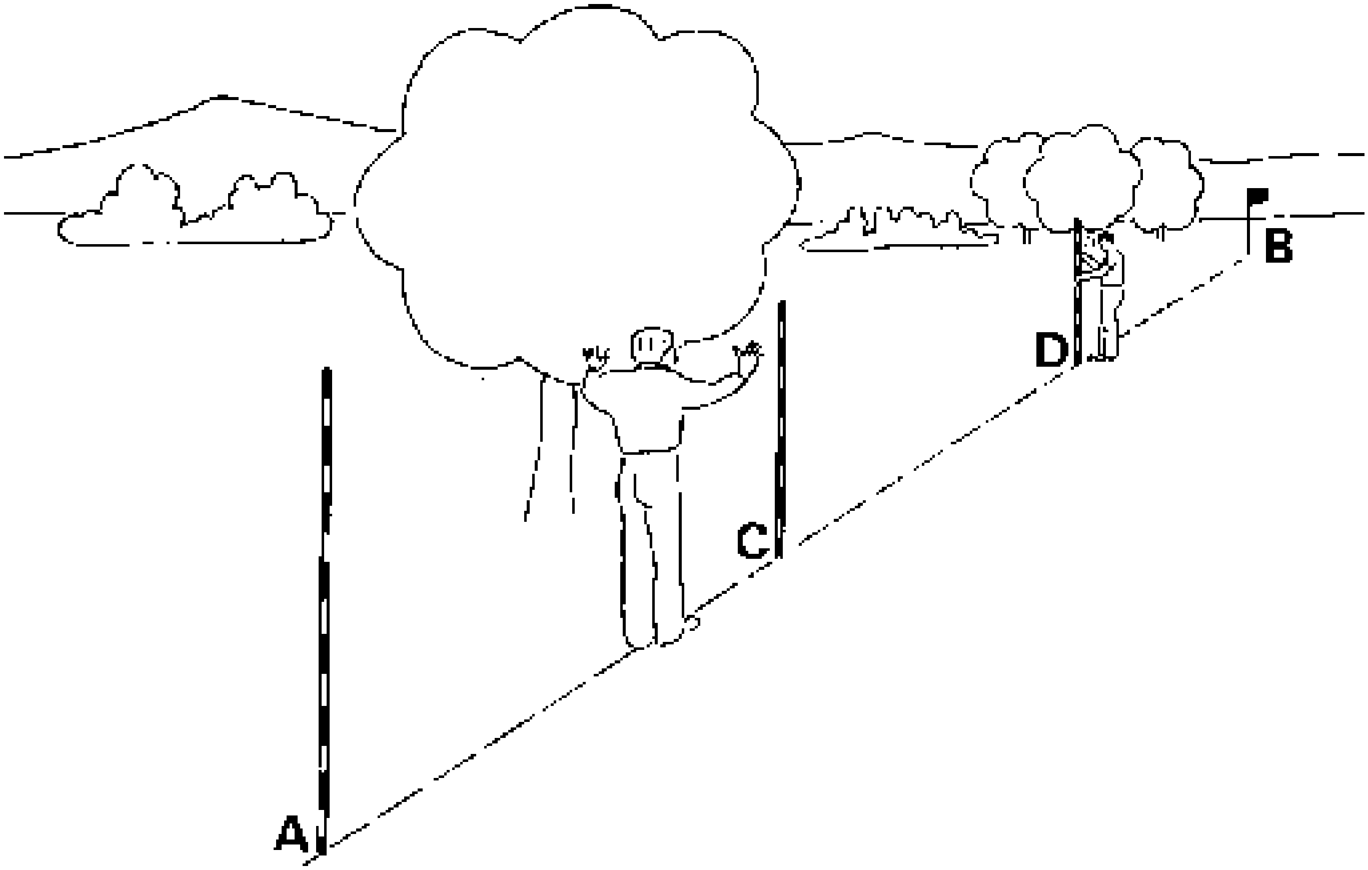
**Fig. 13c Setting out a straight line over a long distance, Step 3**




Step 4

The observer moves back to pole (C) and pole (D) is reset in line with (C) and (B) (see Fig. 13d).

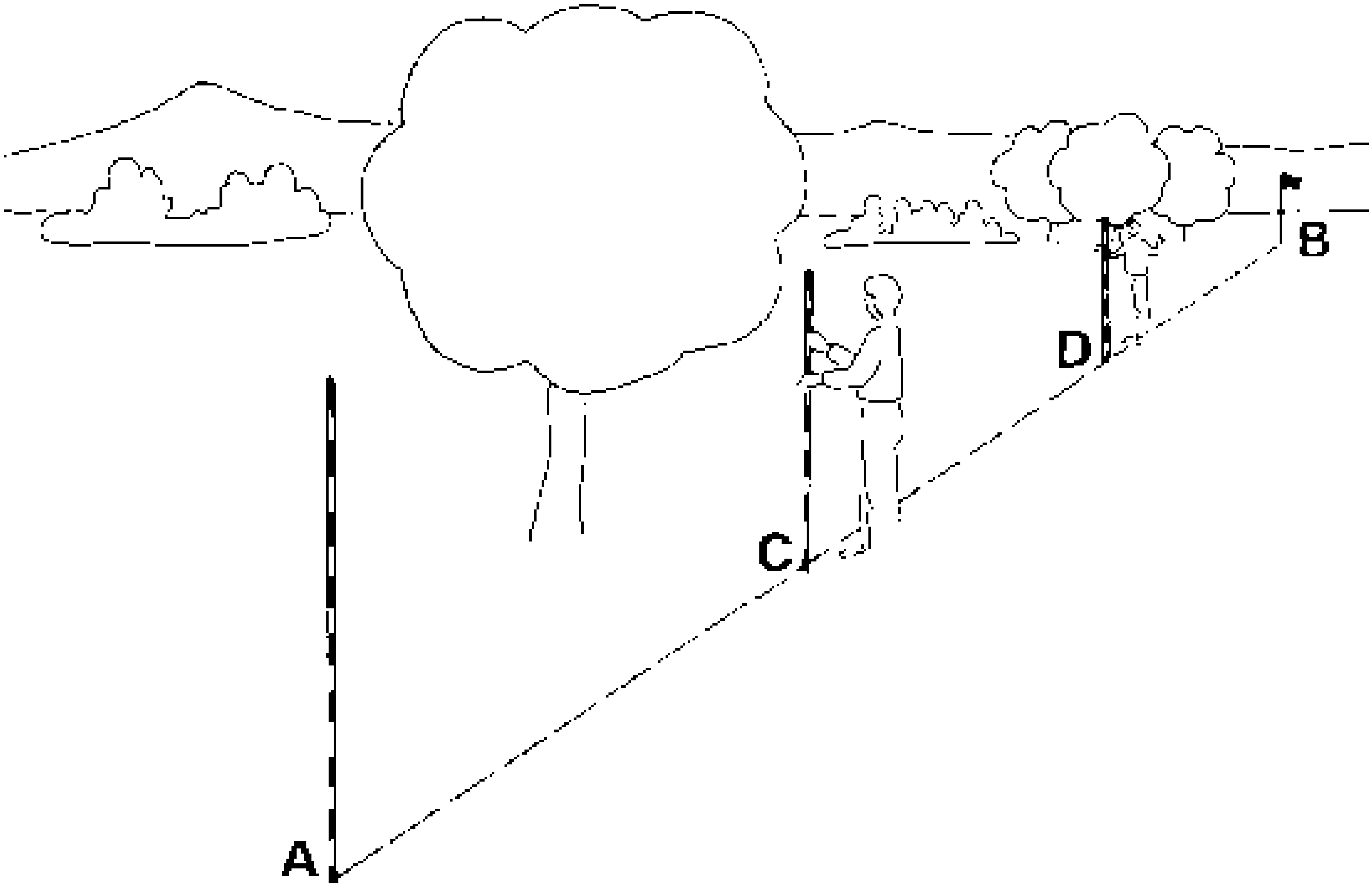
**Fig. 13d Setting out a straight line over a long distance, Step 4**




Step 5

Continue until poles (C) and (D) do not require resetting anymore, which means that all poles (A), (B), (C) and (D) are in line (see Fig. 13e).

**Fig. 13e Setting out a straight line over a long distance, Step 5**




Intermediate poles can now easily be set in line with (A) and (C), (C) and (D), or (D) and (B).

## 2.3.3 Setting out straight lines over a ridge or a hill

Sometimes, a straight line has to be set out between two points (A and B) which are one on each side of a hill, dyke or any other high obstacle (see Fig. 14); standing at point A it is impossible to see point B. A procedure by trial and error is used, which requires two observers and one, or preferably two, assistants.

**Fig. 14 Setting out a straight line over a hill**

Step 1

First, poles (C) and (D) are placed on top of the hill, as accurately as possible in line with (A) and (B), and in such a way that both (C) and (D) can be seen by the observers standing near pole (A) and pole (B) (see Fig. 14a).

**Fig. 14a Setting out a straight line over a hill, Step 1**

Step 2

At the indication of the observer at pole (A), pole (C) is set in line with (A) and (D); in other words pole (C) is moved from position C, (the original position) to position *C2* (see Fig. 14b). [1]

**Fig. 14b Setting out a straight line over a hill, Step 2**

Step 3

At the indication of the observer at pole (B), pole (D) is set in line with (B) and (C); in other words, pole (D) is moved from position D, (the original position) to position D.) (see Fig. 14c).

**Fig. 14c Setting out a straight line over a hill, Step 3**

Step 4

The procedure is repeated: pole (C) is reset in line with (A) and (D) and pole (D) is reset in line with (B) and (C). Continue until no more correction is required, which means that the four poles (A), (B), (C) and (D) are in line (see Fig. 14d).

**Fig. 14d Setting out a straight line over a hill, Step 4**

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# 3. MEASURING DISTANCES



This section indicates, step by step, how to measure short distances, long distances, distances in tall vegetation and horizontal and vertical distances in steep sloping areas.

To measure distances in a field (for example the length and width of a field), a chain or a measuring tape is used. Two men are required, the back man, holding the zero point of the chain (or the tape), and the front man, holding the other end of the chain.

## 3.1 Measuring Short Distances

The following procedure is used when measuring a distance which does not exceed the total length of the chain or the tape.

Step 1

Pegs are placed to mark the beginning and the end of the distance to be measured.

Step 2

The back man holds the zero point of the chain (or tape) at the centre of the starting peg.

The front man drags his end of the chain (or tape) in the direction of the second peg. Before measuring, the chain (or tape) is pulled straight (see Fig. 15).

**Fig. 15 Measurement of a short distance**

Any knots in the tape or entangled links in the chain result in errors in the measurement,

Step 3

When using a measuring tape, the distance between the two pegs can be read directly on the tape by the front man.

When using a chain, the number of links between the two pegs is counted. The total distance is equal to the number of links multiplied by the length of one link (20 cm).

| Distance = number of links x length of one link |
|---|

EXAMPLE: Calculate the distance when given that 30 links have been counted and the length of one link = 0.2 m.

ANSWER: Distance = number of links x length of one link = 30 x 0.2 = 6 m

# 3.2 Measuring Long Distances

Very often, the distance to be measured is longer than the length of the chain 01 the tape. The front man is then provided with short metal pins, called arrows. The arrows are held together by a carrying ring. These arrows are used to mark the position of the end of the chain (or tape) each time it is laid down.

The procedure to follow when measuring long distances is:

Step 1

Pegs are placed (A and B) to mark the beginning and the end of the distance to be measured, and ranging poles are set in line with A and B.

Step 2

The back man holds the zero point at the centre of the starting peg (A). The front mar drags his end of the chain (or tape) in the direction of peg (B). Directed by the back man, he stretches the chain, in line with the ranging poles. Then he plants an arrow to mark the end of the chain (or tape) (see Fig. 16a).

Step 3

Both men move forward with the chain (or tape) and the procedure is repeated, the back man starting this time from the arrow the front man has just planted (see Fig. 16b).

Step 4

The procedure is repeated until the remaining distance between the last arrow and the peg (B) is less than one chain length (see Fig. 16c).

**Fig. 16a Measurement of a long distance Step 2**

**Fig. 16b Measurement of a long distance, Step 3**

**Fig. 16c Measurement of a long distance, Step 4**

Step 5

The remaining distance is measured using the procedure as described in section 3.1.

The number of arrows used during the procedure represents the number of times the full length of the chain (or tape) has been laid out.

The total distance measured is then calculated by the formula:

| Total distance | = number of arrows used x length of the chain (or tape) |
|---|---|

| | |
|---|---|
| | + distance between the last arrow and peg B |

EXAMPLE

The distance between two pegs (A) and (B) has been chained. When reaching peg (B), the back man has used 7 arrows. 23 links have been counted between the last arrow and peg (B), What is the total distance between peg (A) and peg (B)?

Given

number of arrows used by the back man = 7
length of the chain = 20 m
number of links between the last arrow and peg (B) = 23
length of one link = 20 cm = 0.20 m

Answer

Distance between the last arrow and peg (B) = number of links x length of one link = 23 x 0.2 = 4.6 m

Total distance = (number of used arrows x chain length) + (distance between last arrow and peg B) = (7 x 20 m) + 4.6 m = 144.6 m

# 3.3 Measuring Distances in Tall Vegetation

Distances may have to be measured in a field where a tall crop or tall grass is cultivated. The measuring tape (a chain would be too heavy) must then be stretched horizontally by the two men above the crop.

When measuring distances it is important to keep the tape horizontal. Push two arrows or two pegs into the soil to mark the distance to be measured (see Fig. 17). Plumb bobs can be used to check if the measuring tape is indeed horizontal. If horizontal, the free hanging plumb bobs (immediately above the arrows) are perpendicular to the measuring tape. In other words, the measuring tape and the plumb bobs form right angles.

**Fig. 17 Measurement of a distance in a tall growing crop**

# 3.4 Measuring Horizontal and Vertical Distances in Steep Sloping Areas

When measuring distances in a field, reference is always made to horizontal distances. In flat areas, these (horizontal) distances can be measured directly. In steep sloping areas, however, it is Incorrect to assume that the distance measured over the ground surface is the horizontal distance. Thus the horizontal and vertical distances have to be measured separately.

A measuring rod (see Section 1.2), a plumb bob (see Section 1.3) and a carpenter level (see Section 1.4) are used to measure short horizontal and vertical distances in steep sloping areas for example between peg 1 and peg 2 of Fig. 18a.

The procedure to follow is:

Step 1

Two pegs (A and B) are driven into the soil in such a way that their tops are at the same height above the ground level (see Fig. 18a).

**Fig. 18a Measurement of horizontal and vertical distances, Step 1**

Step 2

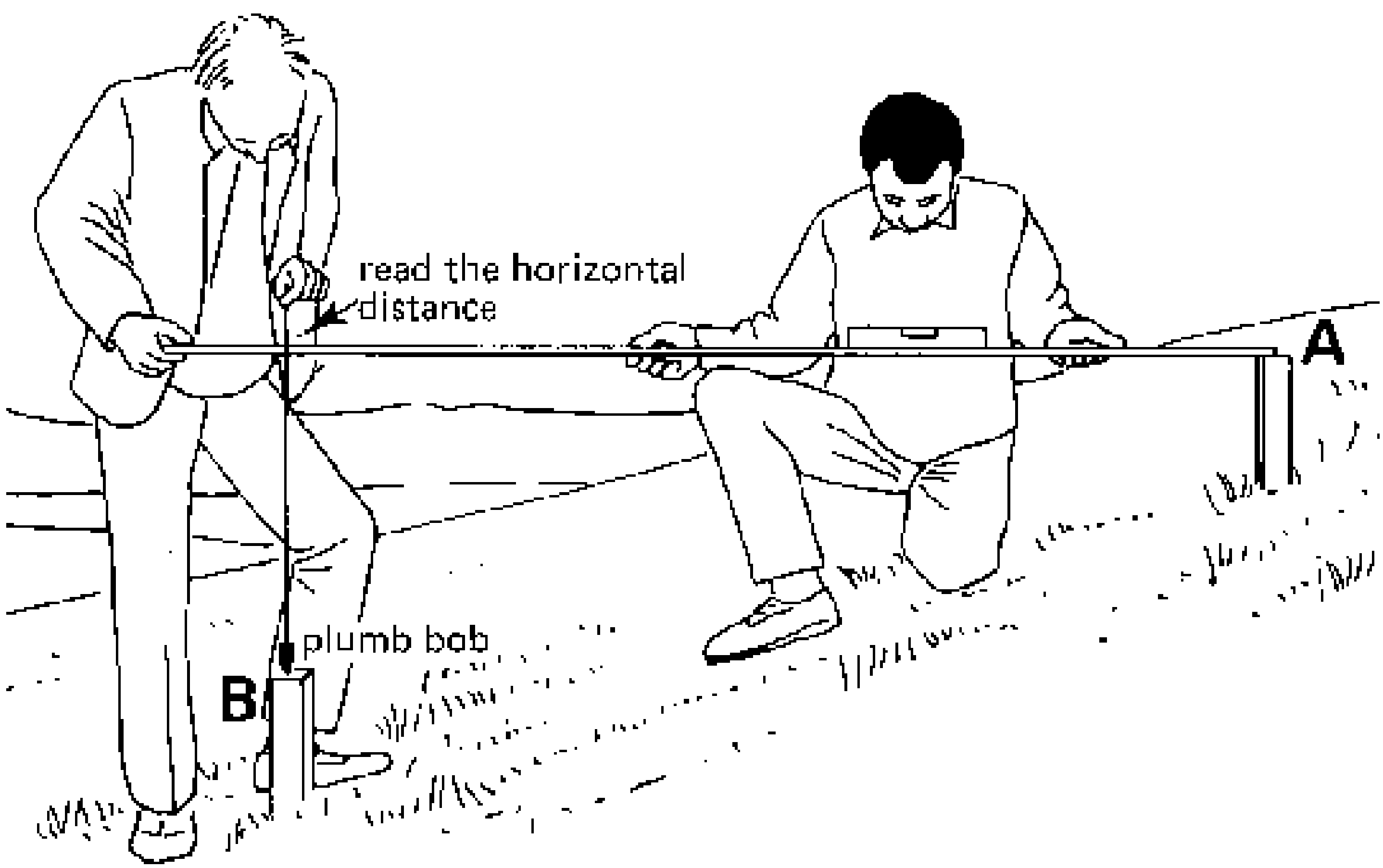
The zero point of the rod is placed on top of peg A. A carpenter level is placed on the rod; move the end of the rod up or down until the bubble of the level is between the marks: the measuring rod is horizontal (see Fig. 18b).

**Fig. 18b Measurement of horizontal and vertical distances, Step 2**

Step 3

Hang a plumb bob just above the centre of peg B and read the **horizontal distance** on the measuring rod (see Fig. 18c).

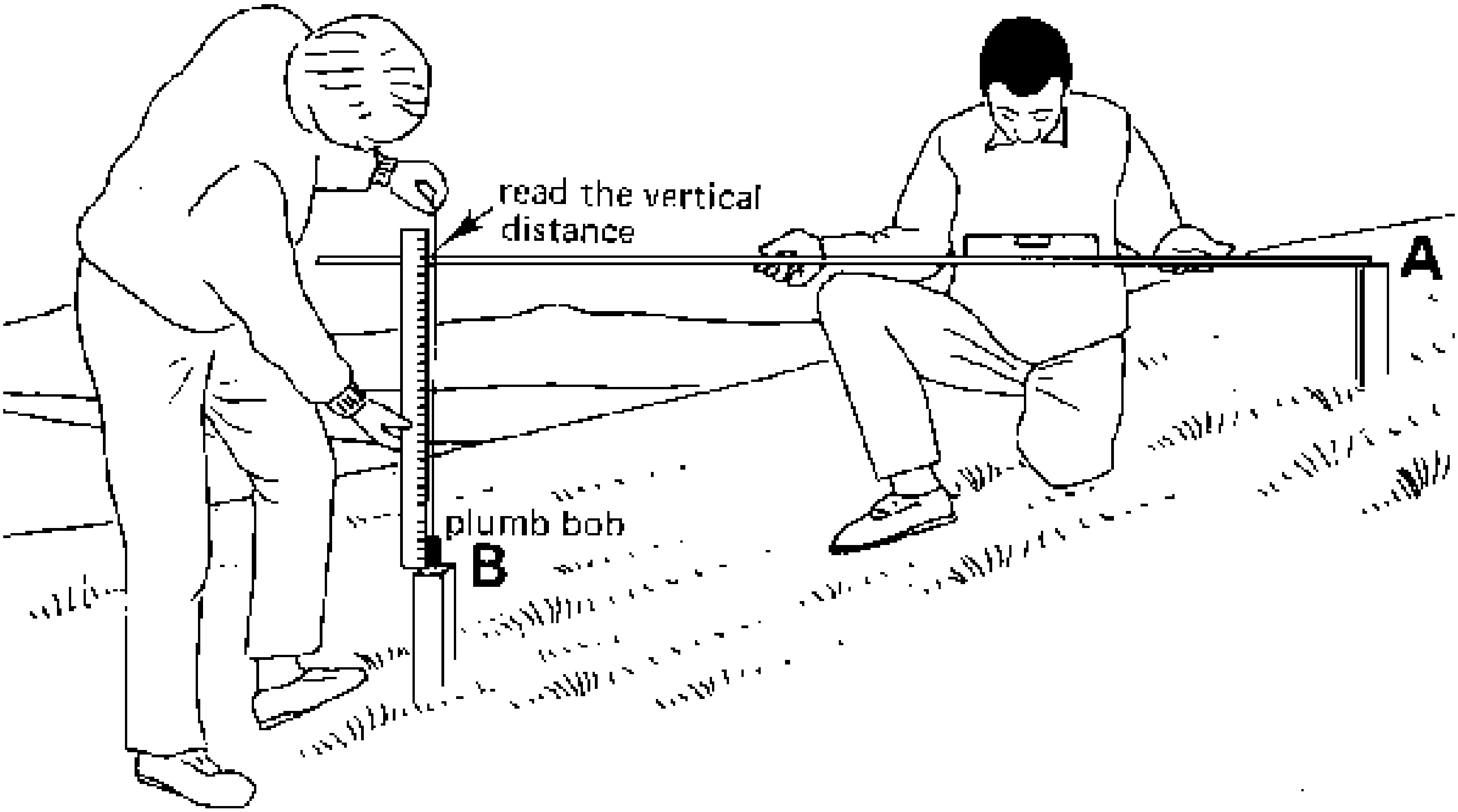
**Fig. 18c Measurement of horizontal and vertical distances, Step 3**




Step 4

The measuring rod is maintained horizontal. The vertical distance between peg A and peg B is measured with a ruler or tape along the plumb bob, from the top of peg B to the bottom of the rod (see Fig. 18d).

**Fig. 18d Measurement of horizontal and vertical distances, Step 4**




Often, however, the distance between the two pegs is longer than the length of the measuring rod. In this case, intermediate pegs are. placed in line with A and B, at intervals of not more than one rod length (see Fig. 19a).

To measure the distances between all the intermediate pegs, steps 1 to 4 (see above) are repeated.

**[Fig. 19a Measurement of horizontal and vertical distances when using intermediate pegs, Step 1]**

**[Fig. 19b Measurement of horizontal and vertical distances when using intermediate pegs, Step 2]**

The total horizontal (or vertical) distance between pegs A and B is the sum of the horizontal (or vertical) distances measured between all the intermediate pegs (see Fig. 19b).

Total horizontal distance: 1.85 + 1.75 + 1.52 = 5.12 m
Total vertical distance: 0.72 + 0.35 + 0.47 = 1.54 m

# 4. SETTING OUT RIGHT ANGLES AND PERPENDICULAR LINES



In survey work, it is often necessary to set out right angles or perpendicular lines on the field. In the sections that follow, a few practical methods indicate how this can be done. These methods include:

- the 3-4-5 method: used to set out a right angle from a certain point on the base line;

- the rope method: used to set out a line perpendicular to the base line, starting from a point which is not on the base line;

- the single prismatic square and the double prismatic square: used to set out both right angles and perpendicular lines.

## 4.1 Setting out Right Angles: the 3-4-5 Method

To set out right angles in the field, a measuring tape, two ranging poles, pegs and three persons are required.

The first person holds together, between thumb and finger, the zero mark and the 12 metre mark of the tape. The second person holds between thumb and finger the 3 metre mark of the tape and the third person holds the 8 metre mark.

When all sides of the tape are stretched, a triangle with lengths of 3 m, 4 m and 5 m is formed (see Fig. 20), and the angle near person 1 is a right angle.

NOTE: Instead of 3 m, 4 m and 5 m a multiple can be chosen: e.g. 6 m, 8 m and 10 m or e.g. 9 m, 12 m and 15 m.

**Fig. 20 The 3-4-5 method**

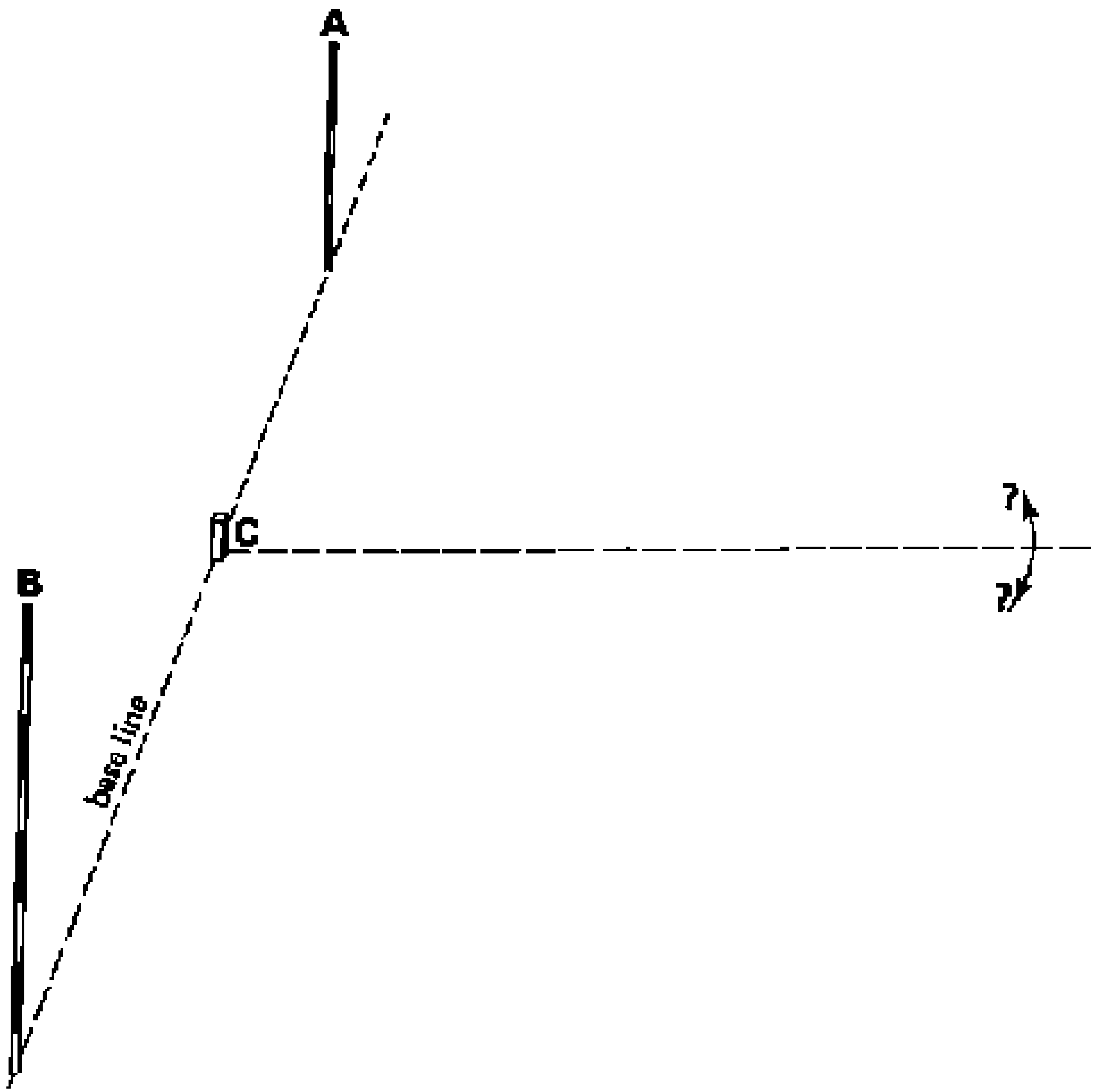
EXAMPLE: Setting out a right angle

Step 1

In Fig. 2 la, the base line is defined by the poles (A) and (B) and a right angle has to be set out from peg

(C). Peg (C) is on the base line.

**Fig. 21a Setting out a right angle, Step 1**




Step 2

Three persons hold the tape the way it has been explained above. The first person holds the zero mark of the tape together with the 12 m mark on top of peg (C). The second person holds the 3 m mark in line with pole (A) and peg (C), on the base line. The third person holds the 8 m mark and, after stretching the tape, he places a peg at point (D). The angle between the line connecting peg (C) and peg (D) and the base line is a right angle (see Fig. 21b). Line CD can be extended by sighting ranging poles.

**[Fig. 21b Setting out a right angle, Step 2]**

Instead of a measuring tape, a 12 m long rope with clear marks at 3 m and 8 m can be used.

# 4.2 Setting out Perpendicular Lines: the Rope Method

A line has to be set out perpendicular to the base line from peg (A). Peg (A) is not on the base line.

A long rope with a loop at both ends and a measuring tape are used. The rope should be a few metres longer than the distance from peg (A) to the base line.

Step 1

One loop of the rope is placed around peg (A). Put a peg through the other loop of the rope and make a circle on the ground while keeping the rope straight. This circle crosses the base line twice (see Fig. 22a). Pegs (B) and (C) are placed where the circle crosses the base line.

Step 2

Peg (D) is placed exactly half way in between pegs (B) and (C). Use a measuring tape to determine the position of peg (D). Pegs (D) and (A) form the line perpendicular to the base line and the angle between the line CD and the base line is a right angle (see Fig. 22b).

**Fig. 22a Setting out a perpendicular line, Step 1**

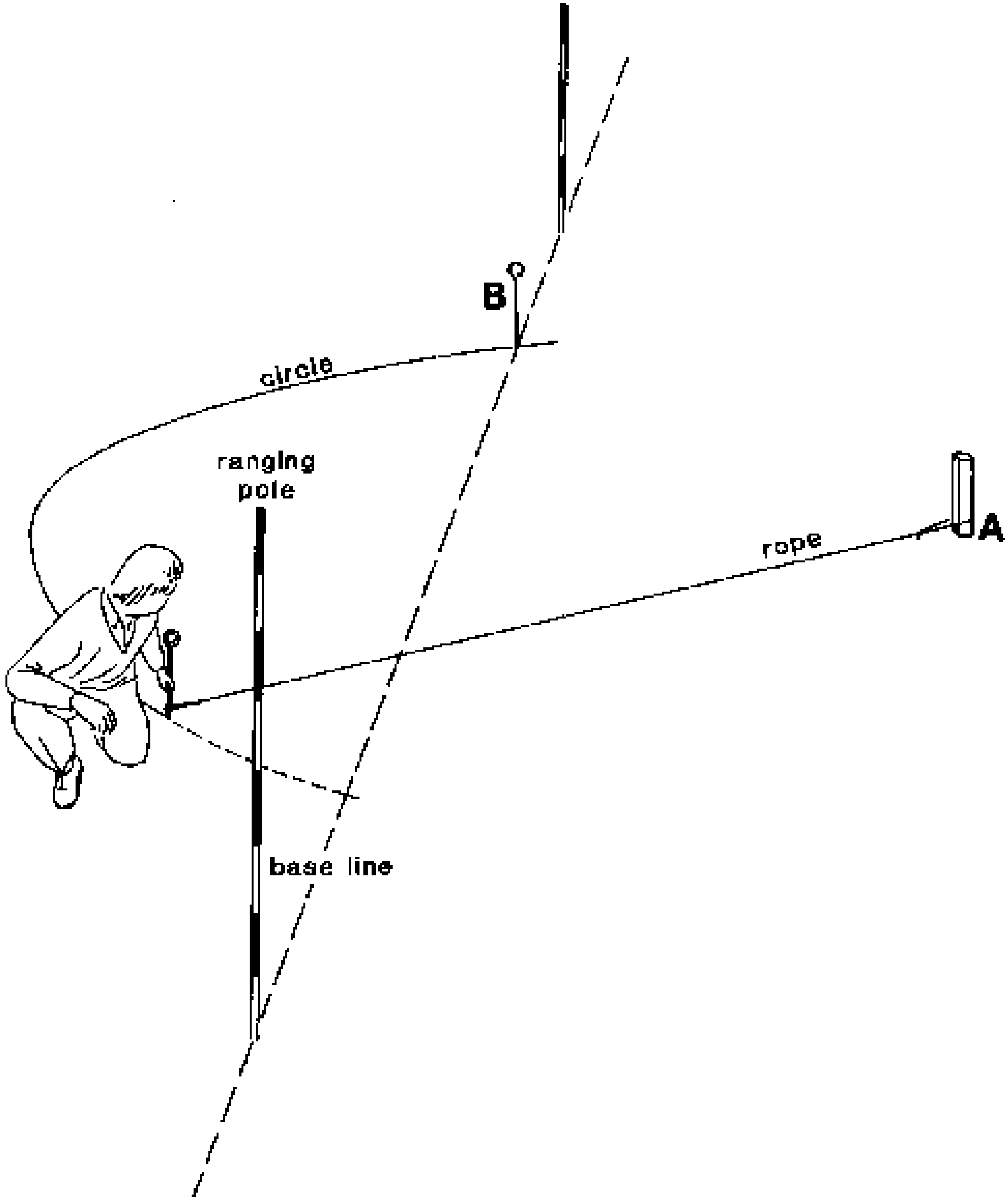
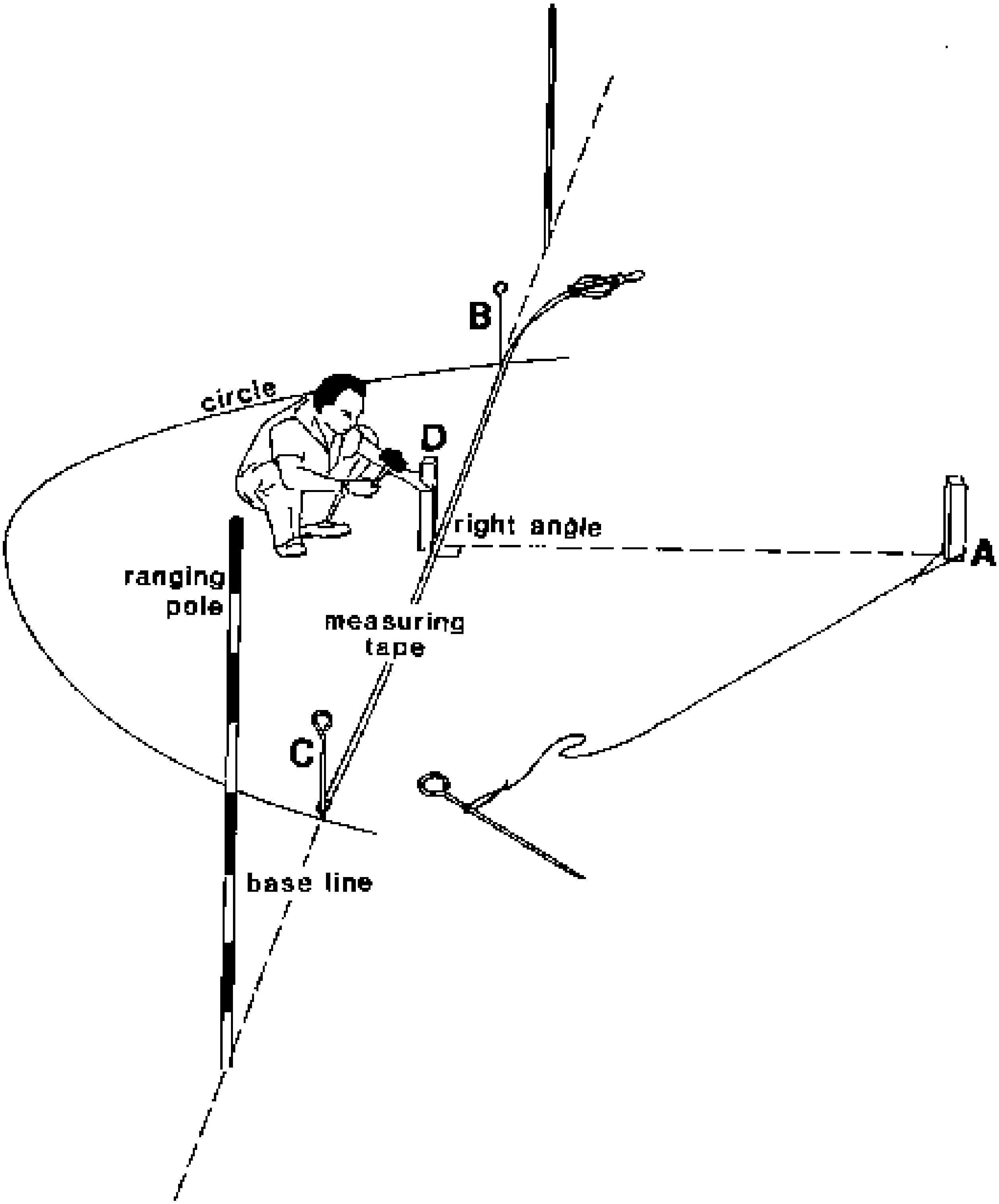



**Fig 22b Setting out a perpendicular line, Step 2**




# 4.3 Optical Squares

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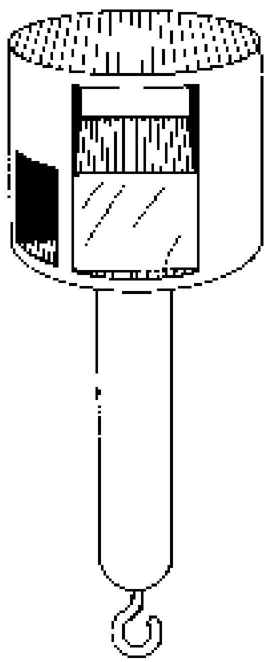
Optical squares are simple sighting instruments used to set out right angles. They can be provided either with mirrors or with one or two prisms. Because of practical difficulties in using squares with mirrors, they have been replaced by squares with prisms: "prismatic squares". There are two major types of prismatic squares: single prismatic squares and double prismatic squares; both will be dealt with in the sections which follow.

## 4.3.1 The single prismatic square



The prism of the single prismatic square is fitted in a metal frame with a handle. Attached to the handle is a hook to which a plumb bob can be connected (see Fig. 23). The special construction of the prism enables to see at right angles when looking through the instrument. The single prismatic square or single prism can be used to set out right angles and perpendicular lines.

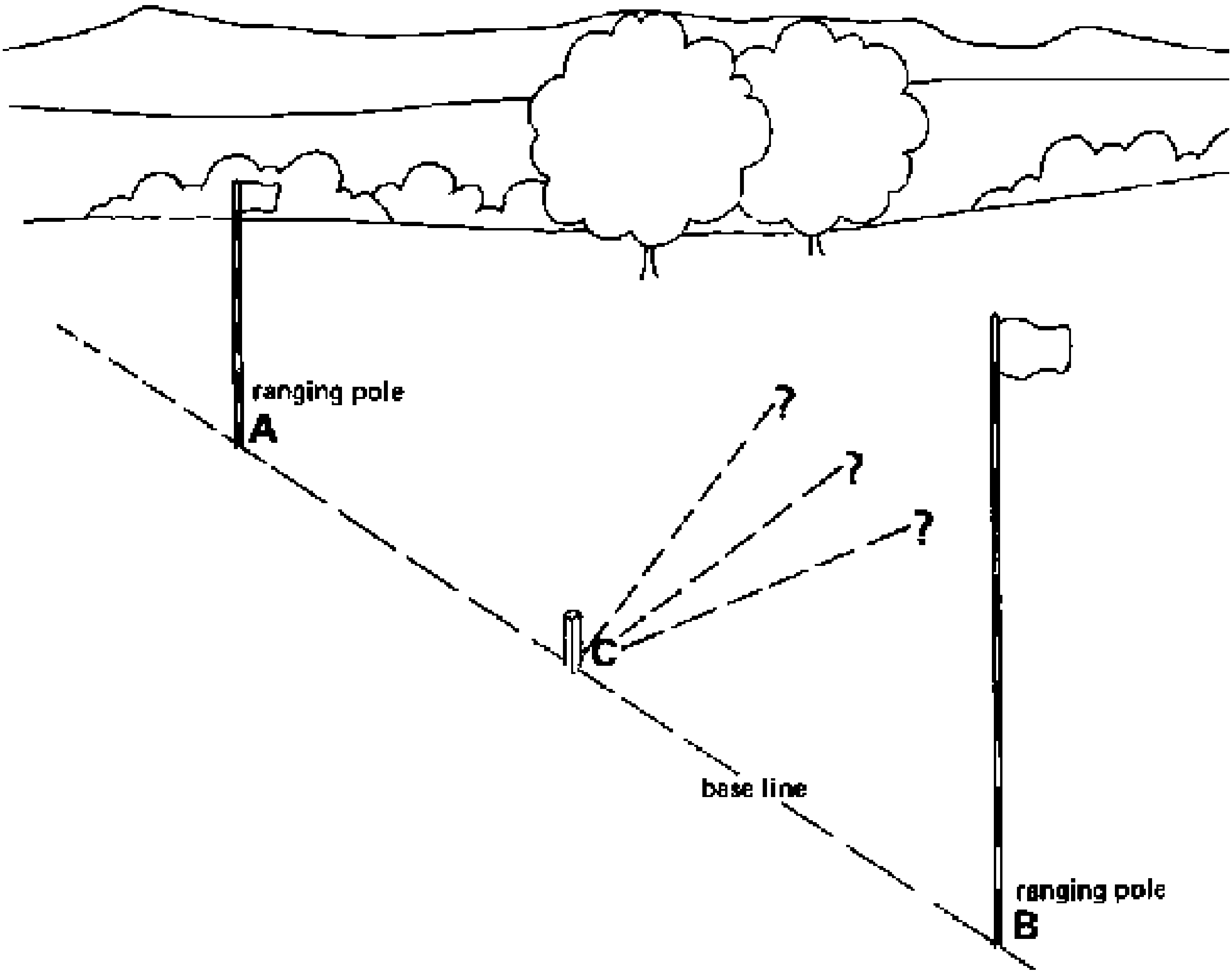
**Fig. 23 A single prismatic square**



### 4.3.1.1 Setting out right angles

In Fig. 24, peg (C) is on the base line which is defined by poles (A) and (B). A right angle has to be set out, starting from peg (C).

**Fig. 24 Setting out a right angle**

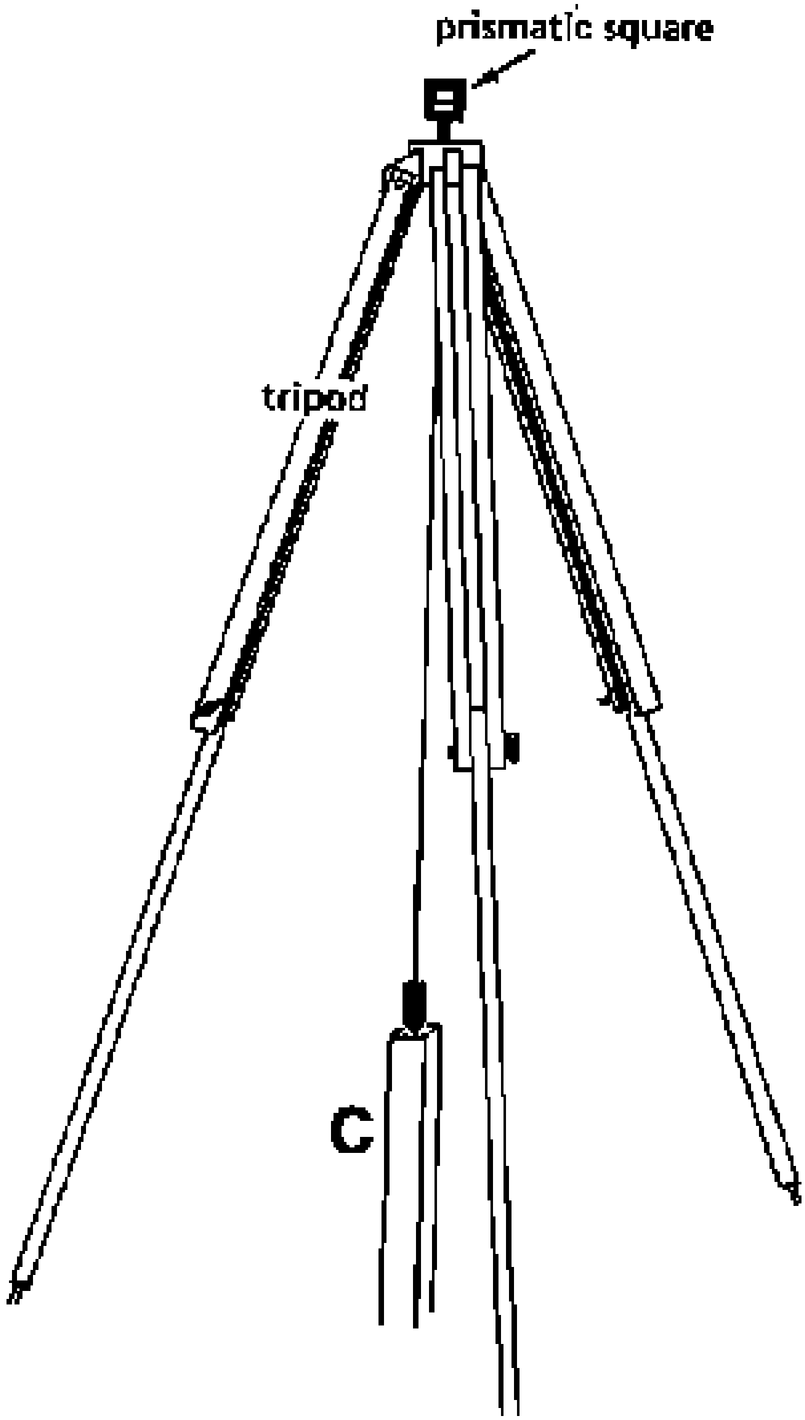



The procedure to follow is:

Step 1

The prismatic square has to be placed vertically above peg (C). This can be achieved by using a plumb bob. The instrument can be hand-held by the operator, but even better is to install the instrument on a tripod (see Fig. 24a).

**Fig. 24a Setting out a right angle, Step 1**




Step 2

The instrument is slowly rotated until the image of pole A can be seen when looking through the instrument (see Fig. 24b).

**Fig. 24b Setting out a right angle, Step 2**

Step 3

An assistant should hold pole (D) in such a way that it can be seen when looking through the opening just above the prism. At the indication of the operator, pole (D) is slightly moved so that pole (D) forms one line (when looking through the instrument) with the image of pole (A) (see Fig. 24c). The line connecting pole (D) and peg (C) forms a right angle with the base line.

**Fig. 24c Setting out a right angle. Step 3**

### 4.3.1.2 Setting out perpendicular lines

In Fig. 25, the base line is defined by poles (A) and (B). A line perpendicular to the base line has to be set out from pole (C); pole (C) is not on the base line.

**Fig. 25 Setting out a perpendicular line**

The procedure to follow is:

Step 1

The operator should stand with the instrument on the base line (connecting A and B). To check this, the assistant, standing behind pole (A) (or B), makes sure that the plumb bob, attached to the instrument, is in line with poles (A) and (B) (see Fig. 25a). The operator then rotates the instrument until the image of pole (A) can be seen.

**Fig. 25a Setting out a perpendicular line, Step 1**

Step 2

The operator then moves the instrument along the base line until he finds a position for which (when looking through the instrument) pole (C) is in line with the image of pole (A) (see Fig. 25b). While searching for the right position, the operator must keep the instrument always in line with poles (A) and (B). This is done under the guidance of the assistant standing behind pole (A).

**Fig. 25b Setting out a perpendicular line, Step 2**

Step 3

When the correct position of the instrument is found, peg (D) is placed right under the plumb bob. The line connecting pole (C) and peg (D) is a line perpendicular to the base line (see *Fig.* 25c).

**Fig. 25c Setting out a perpendicular line, Step 3**

## 4.3.2 The double prismatic square

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The double prismatic square, also called double prism, has two prisms. The two prisms are placed in such a way that it is possible to look at the same time at a right angle to the left and to the right; in addition the observer can look straight ahead of the instrument through openings above and below the prisms (see Fig. 26). It is thus possible to see the base line and the perpendicular line at the same time; no assistant is needed to check if the operator is standing on the base line, as is the case with the single prismatic square.

**Fig. 26 A double prismatic square**

### 4.3.2.1 Setting out right angles

In Fig. 27, peg (C) is on the base line connecting poles (A) and (B). A right angle has to be set out from (C).

**Fig. 27 Setting out a right angle**

Step 1

The observer holds the instrument vertically above peg (C) on the base line. This can be checked with the plumb bob (see Fig. 27a) The instrument is slowly rotated until the image of pole (A), is in line with the image of pole (B) (see Fig. 27a).

**Fig. 27a Setting out a right angle, Step 1**

Step 2

The observer then directs the assistant, holding pole (D), in such a way, that seen through the instrument, pole (D) forms one line with the images of poles (A) and (B) (see Fig. 27b) The line connecting pole (D) and peg (C) forms a right angle with the base line.

**Fig. 27b Setting out a right angle, Step 2**

### 4.3.2.2 Setting out perpendicular lines

In Fig. 28, the base line is defined by poles (A) and (B). A line perpendicular to the base line has to be set out from pole (C) which is not on the base line.

**Fig. 28 Setting out a perpendicular line**

Step 1

Looking through the instrument the observer moves slowly trying to find a position on the base line. When the images of both poles (A) and (B) appear, the observer stops and rotates the instrument slowly until the images of poles (A) and (B) form one line (see Fig. 28a). The instrument is then in line with poles (A) and (B) of the base line.

**Fig. 28a Setting out a perpendicular line, Step 1**

Step 2

The observer moves along the base line towards pole (A) or pole (B). He stops when pole (C) can be seen through the instrument and forms one line with the images of poles (A) and (B) (see Fig. 28b).

**Fig. 28b Setting out a perpendicular line, Step 2**

Step 3

When the correct position of the instrument is found, peg (D) is driven into the soil right under the plumb bob. Peg (D) and pole (C) form the line perpendicular to the base line (see Fig. 28c).

**Fig. 28c Setting out a perpendicular line, Step 3**

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# 5. CALCULATING SURFACE AREAS OF IRREGULAR SHAPED FIELDS



A common problem for a surveyor is the calculation of the surface area of a farmer's field. The fields are often irregular which makes direct calculation of their areas difficult. In such case fields are divided into a number of regular areas (triangles, rectangles, etc.), of which the surfaces can be calculated with simple formulas. All areas are calculated separately and the sum of these areas gives the total area of the field.

## 5.1 Example 1

Figure 29 shows a field with an irregular shape of which the surface area must be determined.

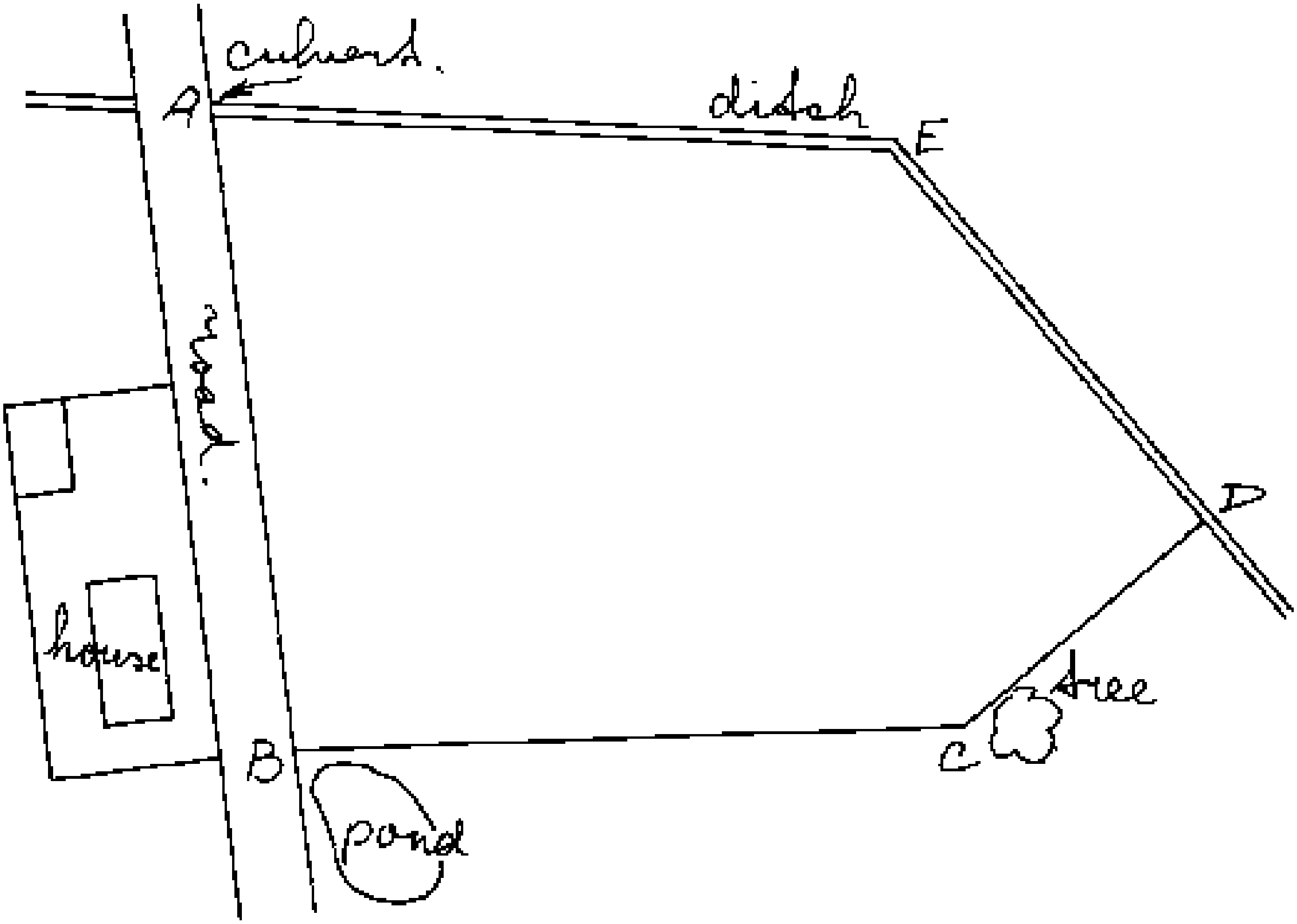
**Fig. 29 A field of irregular shape**

The procedure to follow is:

Step 1

Make a rough sketch of the field (see Fig. 29a) indicating the corners of the field (A, B, C, D and E) and the field borders (straight lines). In addition some major landmark! are indicated (roads, ditches, houses, trees, etc.) that may help to locate the field.

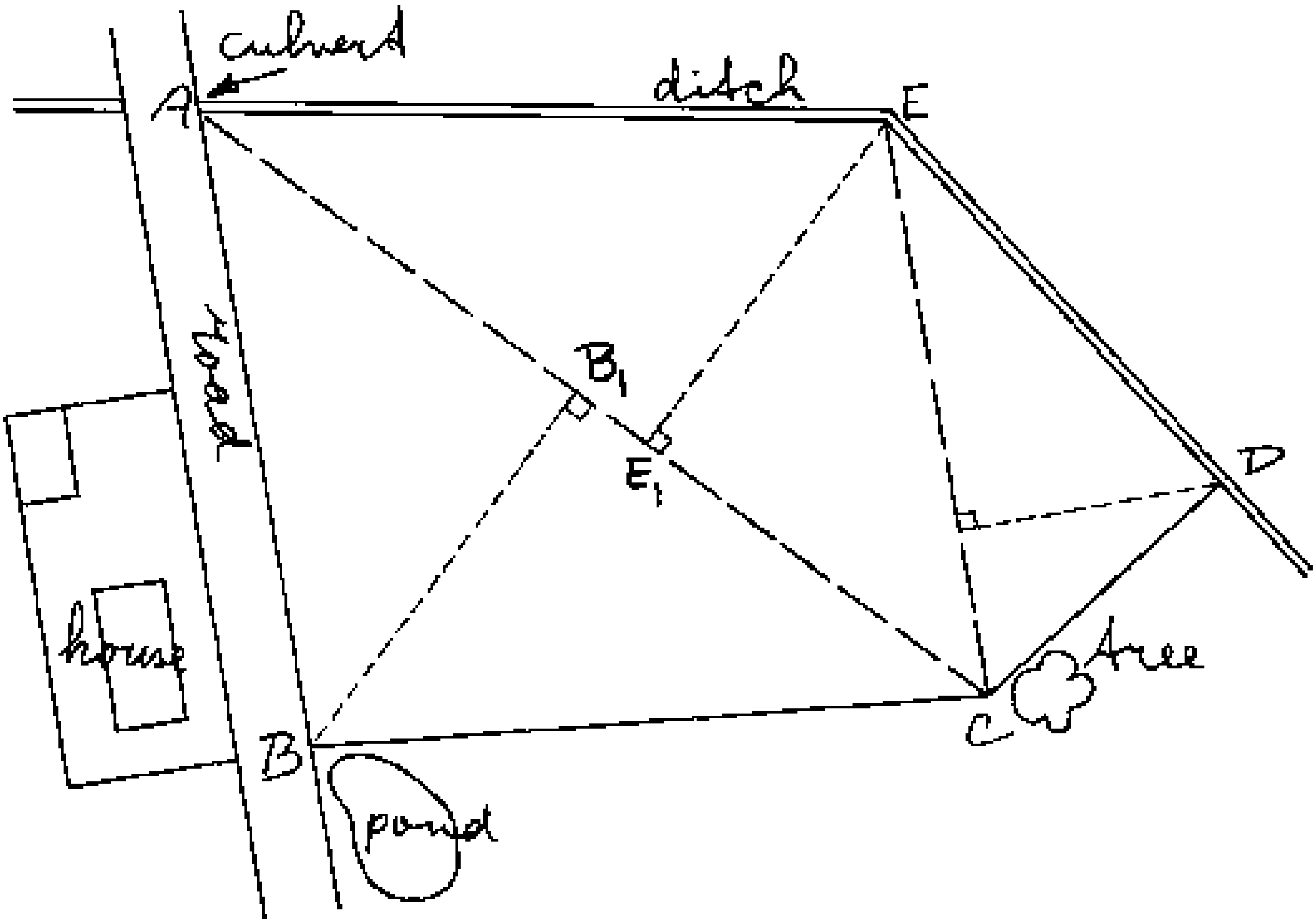
**Fig. 29a A rough sketch of the field**




Step 2

Divide the field, as indicated on the sketch, into areas with regular shapes. In this example, the field can be divided into 3 triangles ABC (base AC and height BB,), AEC (base AC and height $EE_1$) and CDE (base EC and height $DD_1$) (see Fig. 29b).

**Fig. 29b Division of the field into areas with regular shapes**




Step 3

Mark, on the field, the corners A, B, C, D and E with pegs.

Step 4

Set out ranging poles on lines AC (base of triangles ABC and AEC) and EC (base of triangle EDC) (see Fig. 29c) and measure the distances of AC and EC.

**Fig. 29c Mark the corners with pegs and set out ranging poles**

Step 5

Set out line BB (height of triangle ABC) perpendicular to the base line AC (see Fig. 29d) using one of the methods described in Chapter 4. Measure the distance BB,

**Fig. 29d Set out line BB perpendicular to AC**

Step 6

In the same way, the height EE, of triangle AEC and the height DD, of triangle CDE are set out and measured (see Fig. 29e)

**Fig. 29e Set out line $DD_1$ perpendicular to EC and line EE1 perpendicular to AC**

Step 7

The base and the height of the three triangles have been measured. The final calculation can be done as follows:

Measured

Triangle ABC: base = AC = 130 m
height = $BB_1$ = 55 m
Triangle ACE: base = AC = 130 m
height = $EE_1$ = 37 m
Triangle CDE: base = EC = 56 m
height = $DD_1$ = 55 m

Answer

Area = 0,5 x base x height
= 0.5 x 130 m x 55 m = 3 575 $m^2$

Area = 0.5 x 130 m x 37 m = 2 405 m
Area = 0.5 m x 56 m x 55 m= 1 540 $m^2$

Field ABCDE:

Area of triangle ABC = 3 575 $m^2$
Area of triangle ACE = 2 405 $m^2$
Area of triangle CDE = 1 540 $m^2$

Total Area = 3 575 $m^2$ + 2 405 $m^2$ + 1 540 $m^2$
= 7 520 m- = 0.752 ha

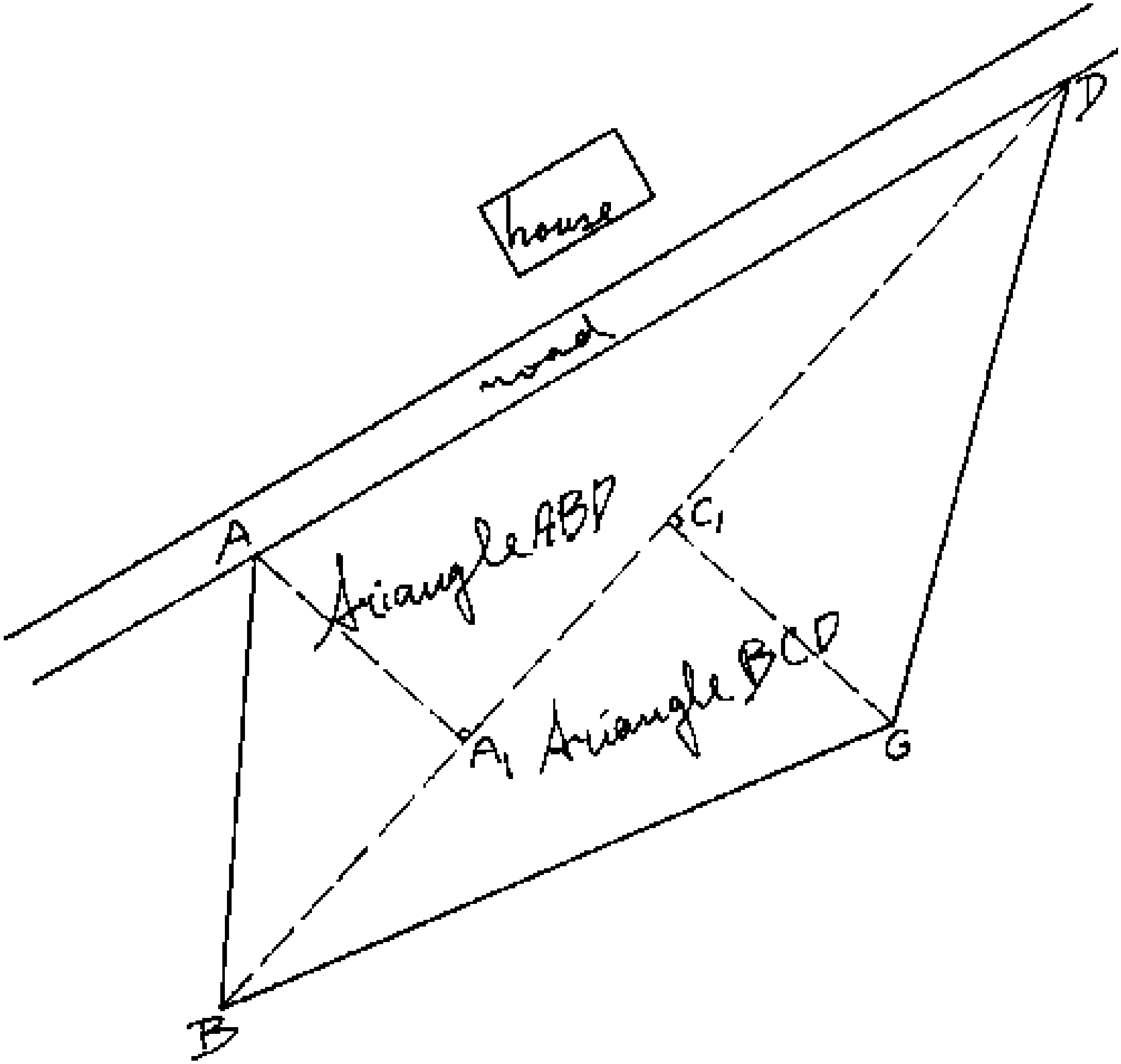
# 5.2 Example 2

The surface area of the field shown in Fig. 30 has to be determined at a time that the field is covered by a tall crop (e.g. maize or sugarcane).

**Fig. 30 A field covered by a tall crop**

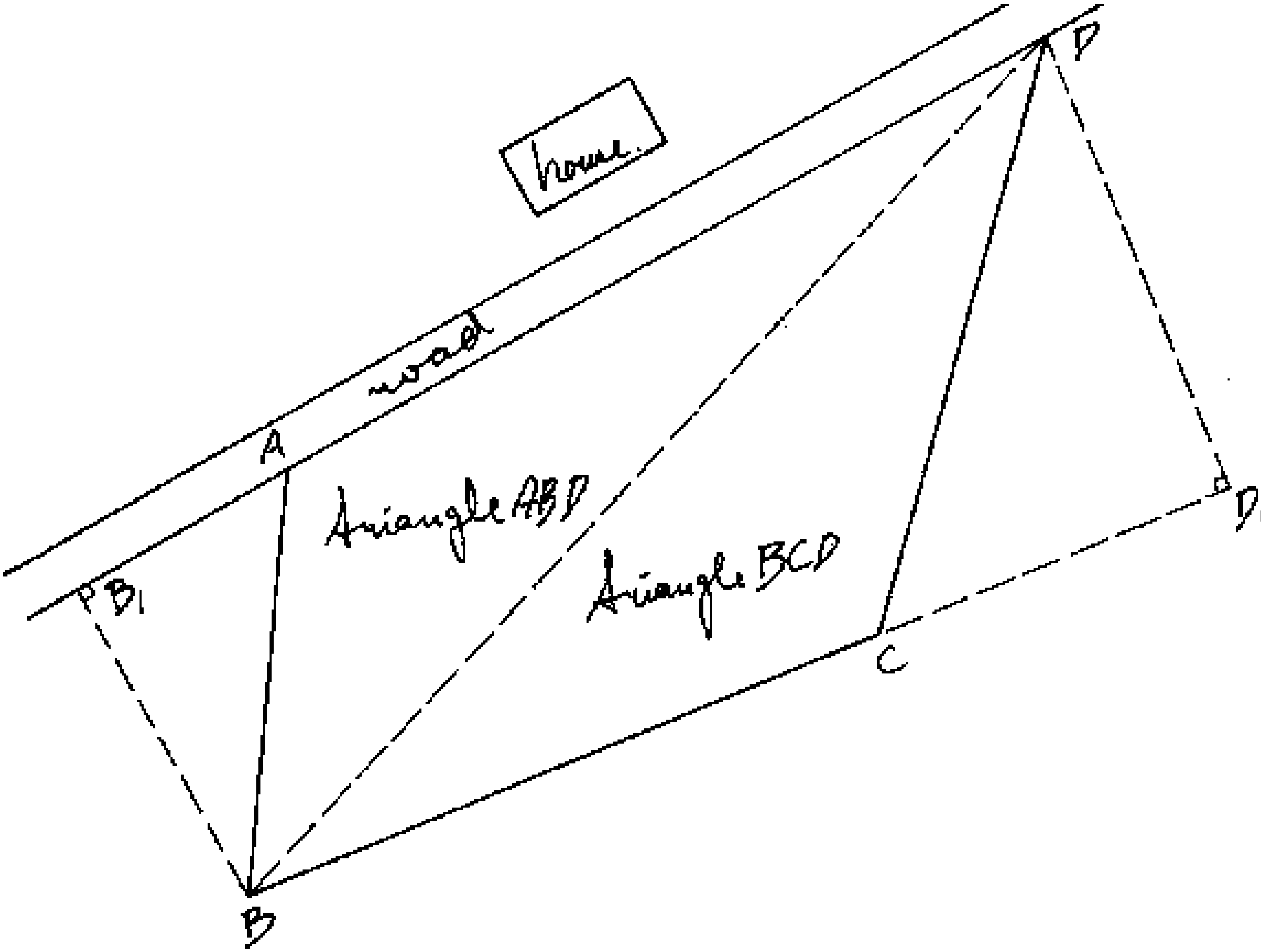
The field can be divided into two triangles ABD and BCD (see Fig. 31a). Unfortunately, because of the tall crop, setting out and measurement of the base BD and the two heights $AA_1$ and $CC_1$ is impossible.

**Fig. 31a Division of the field in two triangles**




In this case, the area of triangle ABD can be calculated using AD as the base and $BB_1$ as the corresponding height. $BB_1$ can be set out and measured outside the cropped area. In the same way, triangle BCD can be calculated using base BC and the corresponding height $DD_1$ (see Fig. 31b).

**Fig. 31b Determination of the areas of the two triangles**




The procedure to follow on the field is:

Step 1

Mark the 4 corners (A, B, C and D) with ranging poles.

Step 2

Line AD is set out with ranging poles and extended behind A. Line BC is also set out and extended behind C (see Fig. 32a). Measure the distances AD (base of triangle ADB) and BC (base of triangle BCD).

**Fig. 32a Measurement of the bases of the two triangles**

Step 3

Set out line $BB_1$ (height of triangle ABD) perpendicular to the extended base line AD using one of the methods described in Chapter 4. In the same way, line $DD_1$ (height of triangle BCD) is set out perpendicular to the extended base line BC (See Fig. 32b) Measure the distance $BB_1$ and $DD_1$.

**Fig. 32b Measurement of the heights of the two triangles**

Step 4

The base and height of both triangles have been measured. The final calculations can be done as follows:

Measured

Triangle ABD: base = AD = 90 m
height = $BB_1$ - 37 m

Triangle BCD: base = BC = 70 m
height = $DD_1$ - 50 m

Answer

Area = 0.5 x base x height
= 0.5 x 90 m x 37 m = 1 665 $m^2$

Area = 0.5 x 70 m x 50 m = 1 750 $m^2$

Field ABDC:

Area triangle ABD = 1 665 $m^2$
Area triangle BCD = 1 750 $m^2$

Total Area = 1 665 $m^2$ + 1 750 $m^2$ = 3 415 $m^2$
= 0.3415 ha $^{=}$ approx. 0.34 ha

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# 6. HORIZONTAL LINES, SLOPES, CONTOUR LINES AND DIFFERENCES IN ELEVATION



Surveying or survey levelling is practised to determine the differences in elevation (= vertical distances) between various points in the field, to measure distances (horizontal distances), to set out contour lines etc. Major surveying works are done by engineers or qualified surveyors using sophisticated equipment such as the levelling instrument (see Fig. 33). This Section will only deal with elementary equipment. Most equipment can be home-made and be used by the farmers themselves after little training.

**Fig. 33 An example of a levelling instrument**

The various types of equipment and their use described in the sections that follow, are:

- Boning rods: horizontal lines and slopes
- N-frame level: slopes and contour lines
- Flexible tube water level: countour lines and differences in elevation
- Hand level: contour lines and differences in elevation.

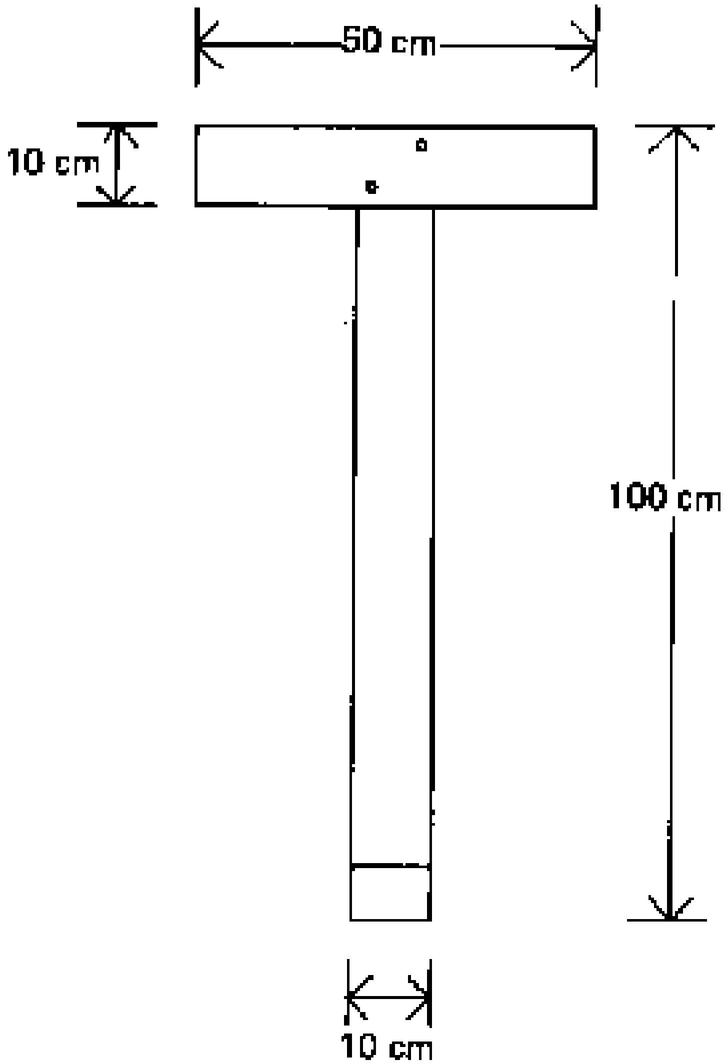
## 6.1 Boning Rods



### 6.1.1 Description

Boning rods are T-shaped and made of wood. Their height is normally 100 cm and the cross-lath is 50 cm x 10 cm. The bottom part is sometimes reinforced with metal (see Fig. 34).

**Fig. 34 A boning rod**




It is important that all boning rods have exactly the same height (100 cm) and while working with the boning rods, the sun should be kept in the back, as it would otherwise be difficult to see them. Usually a total of 3 or 4 boning rods is required.

## 6.1.2 Use of boning rods

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Boning rods are used to set out horizontal lines or lines with a constant slope. In particular they are used for setting out canal excavation works, but also for roads and dyke construction.

To be able to set out horizontal lines or lines with a constant slope, the elevation (or height) of two points on the line (preferably the starting and end points) must be known.

### 6.1.2.1 Setting out horizontal lines

Suppose a horizontal line has to be set out between the Bench Marks A and B. Bench marks A and B have the same elevation. The procedure is:

Step 1

Set out a straight line between A and B (see Chapter 2) and place intermediate pegs at regular intervals (see Fig. 35a; pegs C and D).

**Fig. 35a Setting out a horizontal line, Step 1**

Step 2

Place boning rods on top of the two Bench Marks and on top of peg C. The observer, looking just over the top of boning rod A tries to bring the tops of the boning rods A, B and C in line.

As can be seen from Fig. 35b, boning rod C and thus peg C is too high; the tops of the boning rods are not in line.

**Fig. 35b Setting out a horizontal line, Step 2**

Step 3

Hammer peg C further into the soil. It may be necessary to excavate some of the soil surrounding peg C in order to be able to lower peg C sufficiently.

The top of peg C is at the correct elevation when, looking over the top of boning rod A, the tops of the boning rods A, C and B are in line (see Fig. 35c).

**Fig. 35c Setting out a horizontal line, Step 3**

Step 4

Place a boning rod on peg D. When looking over the tops of the boning rods A and B it is not possible to see the top of the boning rod on peg D, as peg D is too low (see Fig. 35d).

**Fig. 35d Setting out a horizontal line, Step 4**

Step 5

Replace peg D by a longer peg or pull out peg D and add some soil in the immediate surroundings of D and hammer peg D again into the soil. Repeat this process until the correct elevation of peg D is found (see Fig. 35e).

**Fig. 35e Setting out a horizontal line, Step 5**

Step 6

The two Bench Marks A and B and the pegs C and D all have the same elevation. Line ACDB is horizontal (Fig. 35f).

**Fig. 35f Setting out a horizontal line, Step 6**

#### 6.1.2.2 Setting out slopes

The use of boning rods when setting out a slope is the same as described in 6.1.2.1 only, in this case, the Bench Marks A and B do not have the same elevation. Bench Mark A is either higher or lower than B. When the difference in elevation and the horizontal distance between A and B are known, the slope can be calculated (see Volume I, Chapter 3 and Volume 2 Chapter 3 and sections 6.3 and 6.4).

# 6.2 The N-Frame Level

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## 6.2.1 Description

This instrument, used to set out contour lines or slopes, consists of a wooden frame (a main lath, 2 legs and 2 cross poles) as shown in Figure 36a. On the main lath, a carpenter level is firmly fixed (e.g. with metal strips).

## 6.2.2 Testing the N-frame level

Before fixing the carpenter level to the frame, the instrument must be tested to make sure that the carpenter level is in the correct position.

The frame is placed on two points which have the same elevation (for example on a horizontal table or on a floor that has been checked previously with the carpenter level). If the bubble of the level tube is not exactly in between the marks, the carpenter level must be adjusted by putting a spacer (e.g. thin piece of board) under one end of the level (see Fig. 36a and b).

**Fig. 36a The N-frame level**

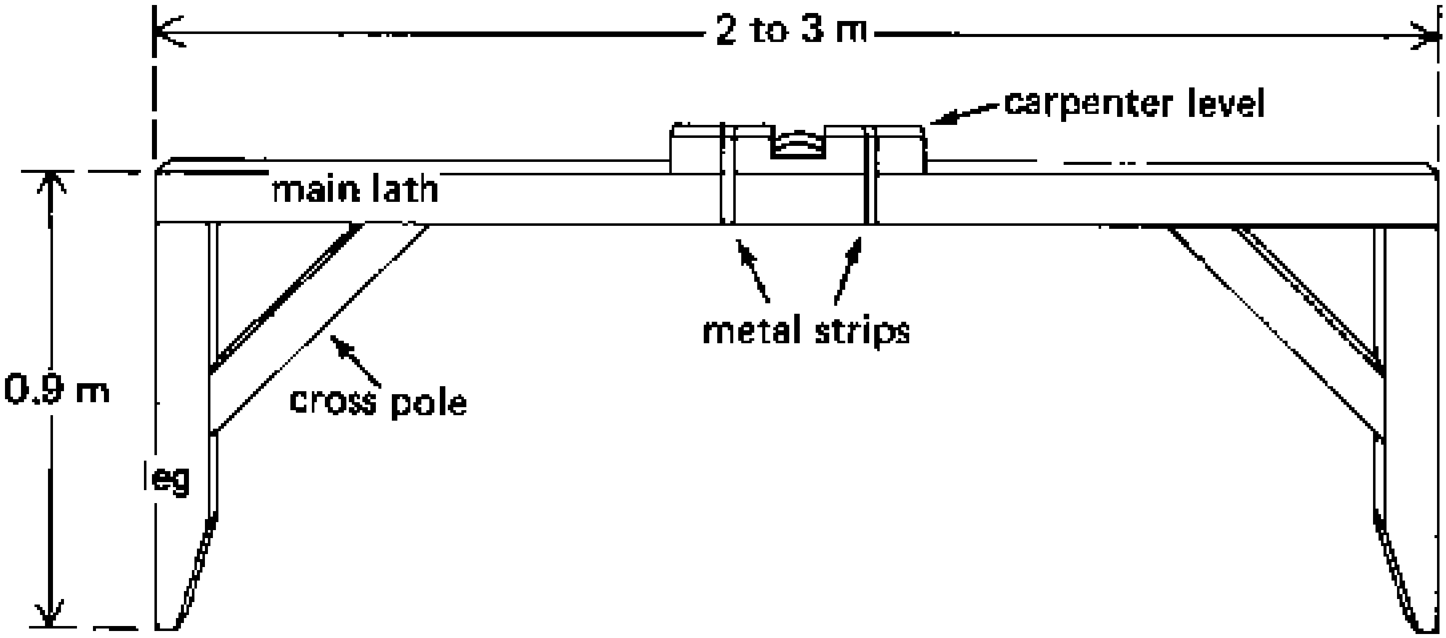


Fig. 36b Testing the N-frame level

## 6.2.3 Use of the N-frame level

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The N-frame level is used to set out contour lines and slopes on the field.

### 6.2.3.1 Setting out contour lines

Starting from peg (A), a contour line has to be set out. The procedure to follow is:

Step 1

One leg of the instrument is placed close to peg (A). By turning the frame around this leg, a position of the frame is found such that the second leg is on the ground and the bubble of the carpenter level is in between the marks. This means that the spot thus found by the second leg of the frame is at the same elevation as the starting point. Both points belong to the same contour line. A new peg (peg B) is driven in close to the second leg to mark the place (see Fig. 37 a).

Fig. 37a Setting out a contour line, Step 1

Step 2

The N-frame is moved to the newly-placed peg and the procedure is repeated until the end of the field is reached. All the pegs, thus driven in the ground, form a contour line (see Fig. 37b).

Fig. 37b Setting out a contour line, Step 2

Step 3

When the first contour line has been pegged out it might be necessary to make minor adjustments by moving some of the pegs to the left or to the right to find a smooth line. Most of the pegs will remain in the same place. The smooth line thus formed by the pegs represents the first contour line.

Step 4

The next step is to determine the second contour line. A choice has to be made on how many centimetres lower (or higher) the next contour line should be. This choice should be based on the required accuracy (a little difference in height means it is more accurate), the general slope of the area and the regularity of the general slope of the area. In practice, the height difference will vary between 10 and 50 cm.

In this example, a height difference of 20 cm was chosen. This means that the ground level near peg A should be 20 cm higher than the ground level near peg A (see Fig. 38). The position of peg A. is found by trial and error, using e.g. the method described in section 3.4 to measure the vertical distance between the ground levels near A and A1. peg (A1) represents the starting point of the second contour line. Now follow the procedure described above to determine the second contour line (see Fig. 38).

**Fig. 38 Setting out the second contour line**

### 6.2.3.2 Setting out slopes

In addition to the determination of contour lines the N-frame level can be used to set out lines with a uniform slope, which is useful, e.g. for setting out furrows or ditches.

Example

Suppose that the slope of a ditch to be set out on the field is 1% (one percent). In order to use the N-frame level to set out slopes, it requires a modification; one leg has to be shortened. In this example, one leg has to be shortened by 2 cm, as the length of the main lath is 2 m and the required slope is 1%. (Note 1% of 2 m = 2 cm). See

**Fig. 39 Modified N-frame level**

A slope of 1.5% would require one Leg to be 3 cm (1.5% of 2 m) shorter; a slope of 2% would require a 4 cm (2% of 2 m) shorter leg.

Step 1

The shortest leg of the N-frame is placed close to the starting peg (A). By turning the N-frame around this leg, a position is found such that the second leg is on the ground and the bubble of the carpenter level is in between the marks. The spot thus found is 2 cm lower than the starting point and is marked with a new peg (peg B)(see Fig. 40a).

**Fig. 40a Setting out a slope, Step 1**

Step 2

The N-frame is moved and the short leg is placed near peg (B). The procedure is repeated until the end of the field is reached. The succession of pegs thus placed form a line with a slope of 1% (see Fig. 40b).

This line would be, after correction, the centre line of a ditch with a slope of 1%.

**Fig. 40b Setting out a slope, Step 2**

# 6.3 The Flexible Tube Water Level

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## 6.3.1 Description

The flexible tube water level, used for contour lines and measuring differences in elevation, consists of two staffs with a length of about 2 m and a transparent flexible tube of about 14 m long. The ends of the tube are firmly fixed to the staffs (see Fig. 41).

Sometimes, a 10 m long rope is fixed to the staffs to limit the distance between the staffs. The rope thus helps to prevent damage to the tube.

## 6.3.2 Use of the flexible tube water level

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The tube is filled with muddy water so that the water level is about 1 m high in each of the tube ends. It is essential Chat no air bubbles are trapped in the tube. Air bubbles can be removed by tapping the tube with the finger.

Wherever the two staffs are set, the free water surfaces in the tube ends have the same level (see Fig. 42). This is called the "communicating vessel" principle.

**Fig. 41 Flexible tube water level**

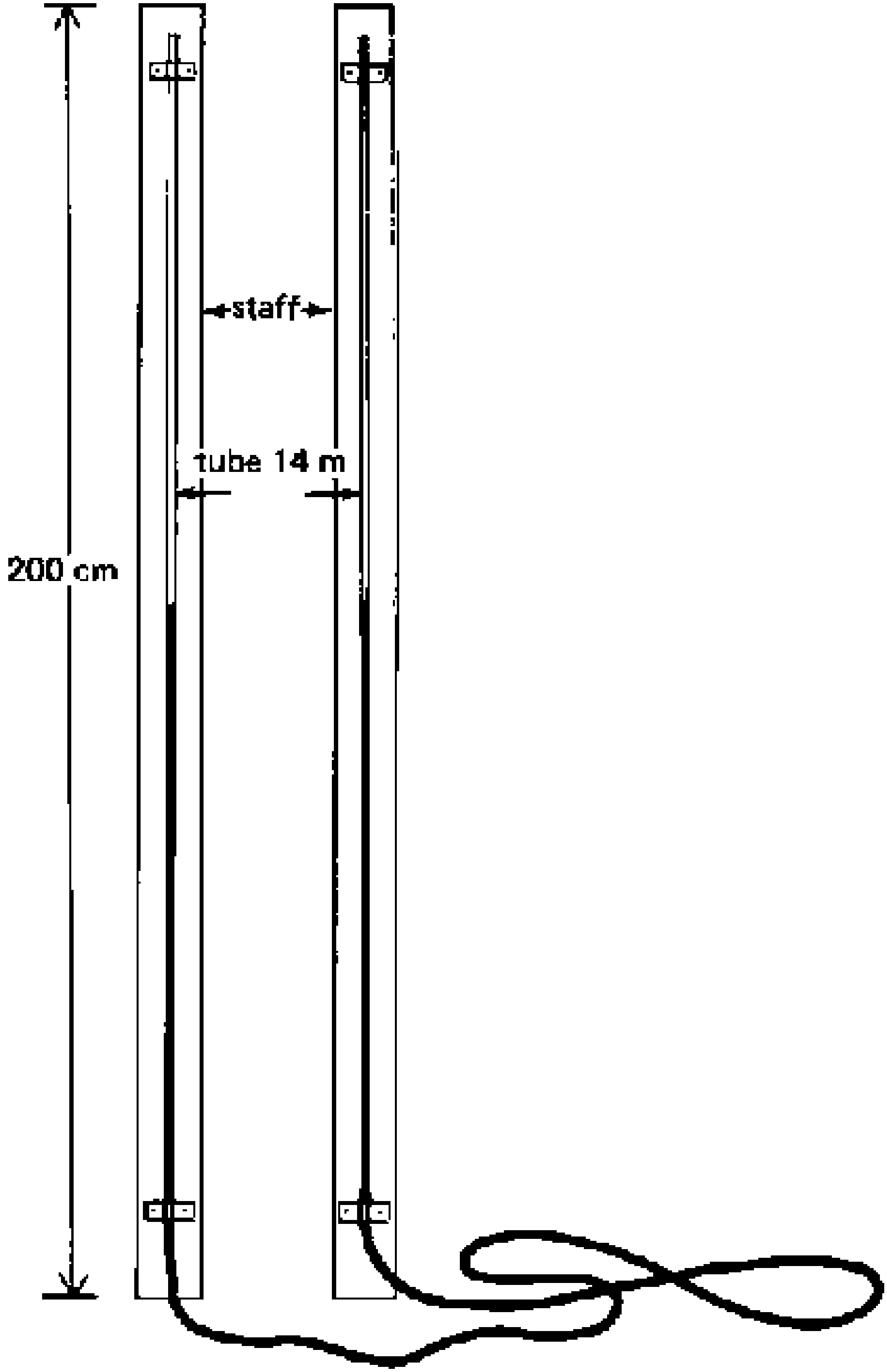
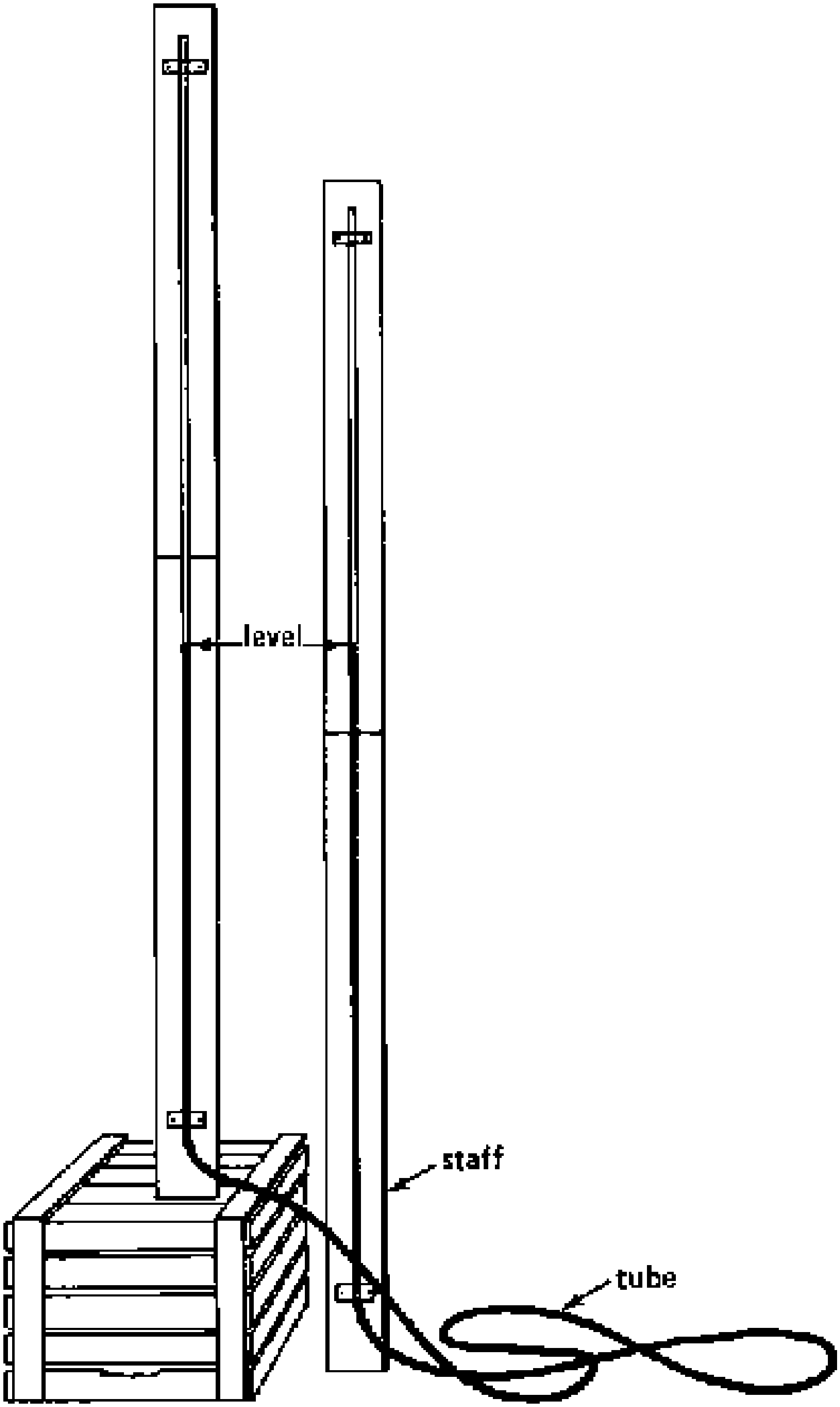



**Fig. 42 The "communicating vessel" principle**




### 6.3.2.1 Setting out contour lines

To set out a contour line with a Cube water level, the following procedure is used:

<u>Step 1</u>

The two staffs are placed back to back at the starting point marked with peg (A). After the air bubbles have been removed and the water has come to a rest, a mark is made on both staffs, indicating the water level (see Fig 43a).

Step 2

The lead man takes one staff and drags the tube in what seems to be the direction of the contour line. When the tube is almost stretched, the lead man moves slowly up and down the slope until he obtains a position where the water level coincides with the mark (see Fig. 43b).

**Fig. 43a Setting out a contour line, Step 1**

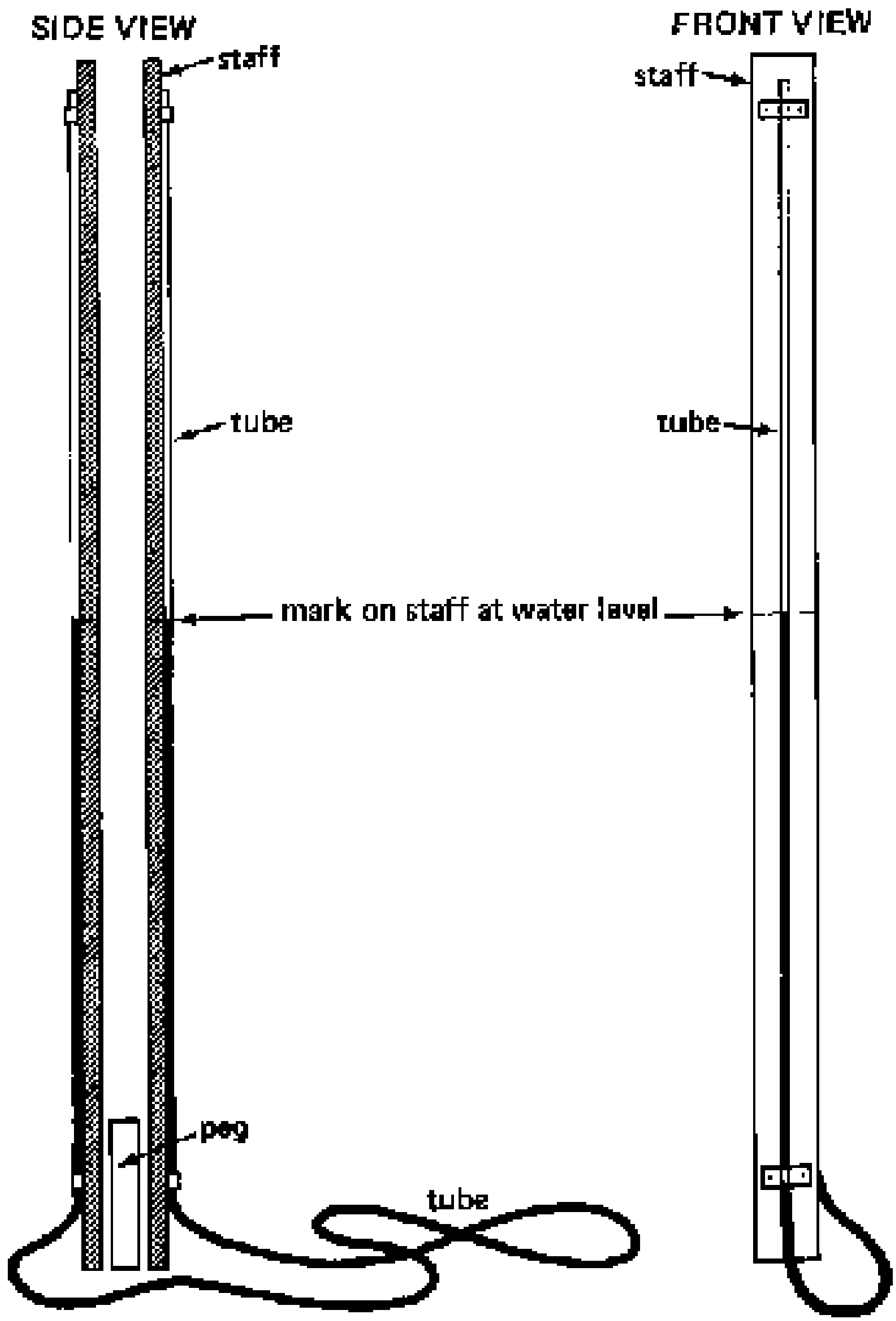


**Fig. 43b Setting out a contour line, Step 2**

The point where the staff is then standing is at the same level as the starting point. A second peg (peg B) is placed at this point.

Step 3

The procedure is repeated, starting from peg (B), to find the third point (peg C) of the contour line.

Care should be taken to avoid spilling water whenever the staffs are moved. For this purpose, the ends of the tube can be closed with plugs during transport. It is essential to remove the plugs during the measurements, otherwise the communicating vessels principle is not applicable anymore and measurements will be wrong.

### 6.3.2.2 Measuring differences in elevation

For the measurement of differences in elevation between two points in the field, the tube water level is adapted. Each staff is graduated in centimetres and used as a measuring staff. The zero point usually coincides with the foot of the staff (see Fig. 44).

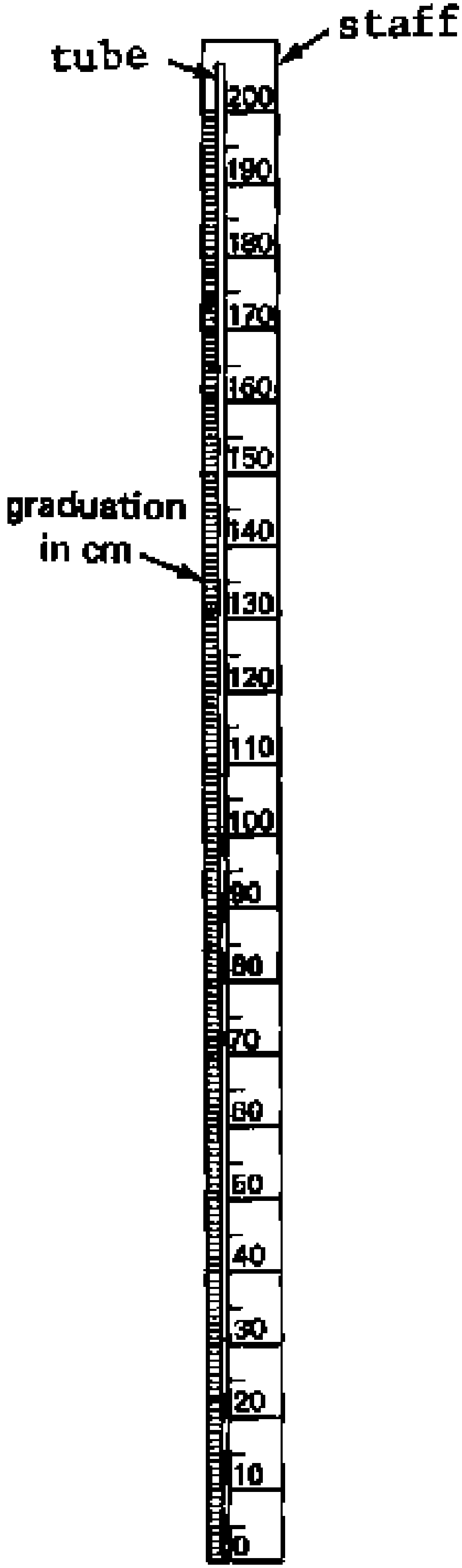
A. Measuring the difference in elevation between two close points

Suppose the difference in elevation between two points A and B has to be measured; A and B are less than 10 m apart.

The first staff is set on point A and the second staff on point B (see Fig. 45). After the water level in both stand tubes comes to a rest, a reading is made on both staffs. The difference in elevation between points A and B is calculated by the formula:

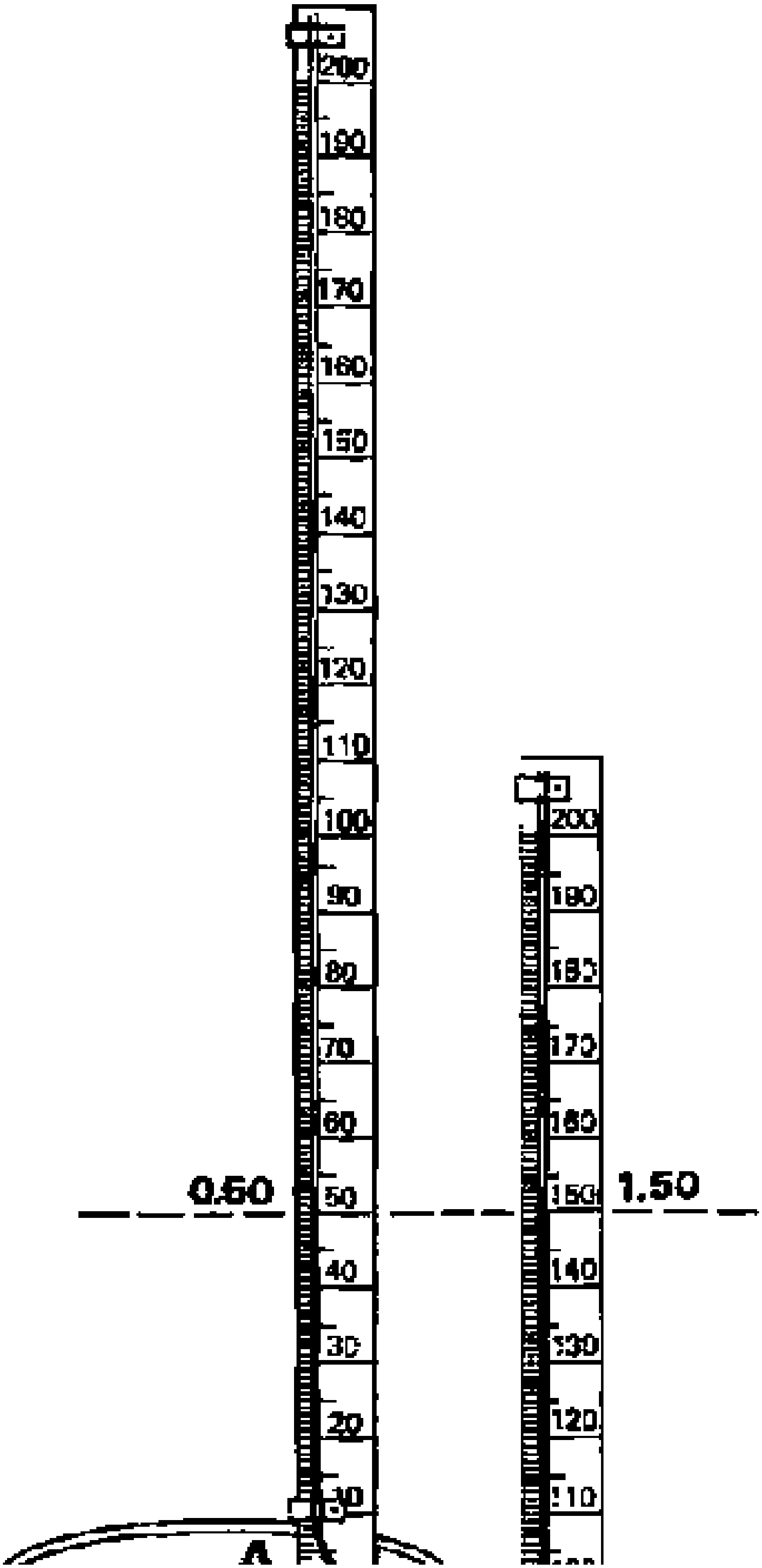
| |
|---|
| Difference in elevation between A and B = reading on staff A - reading on staff B |

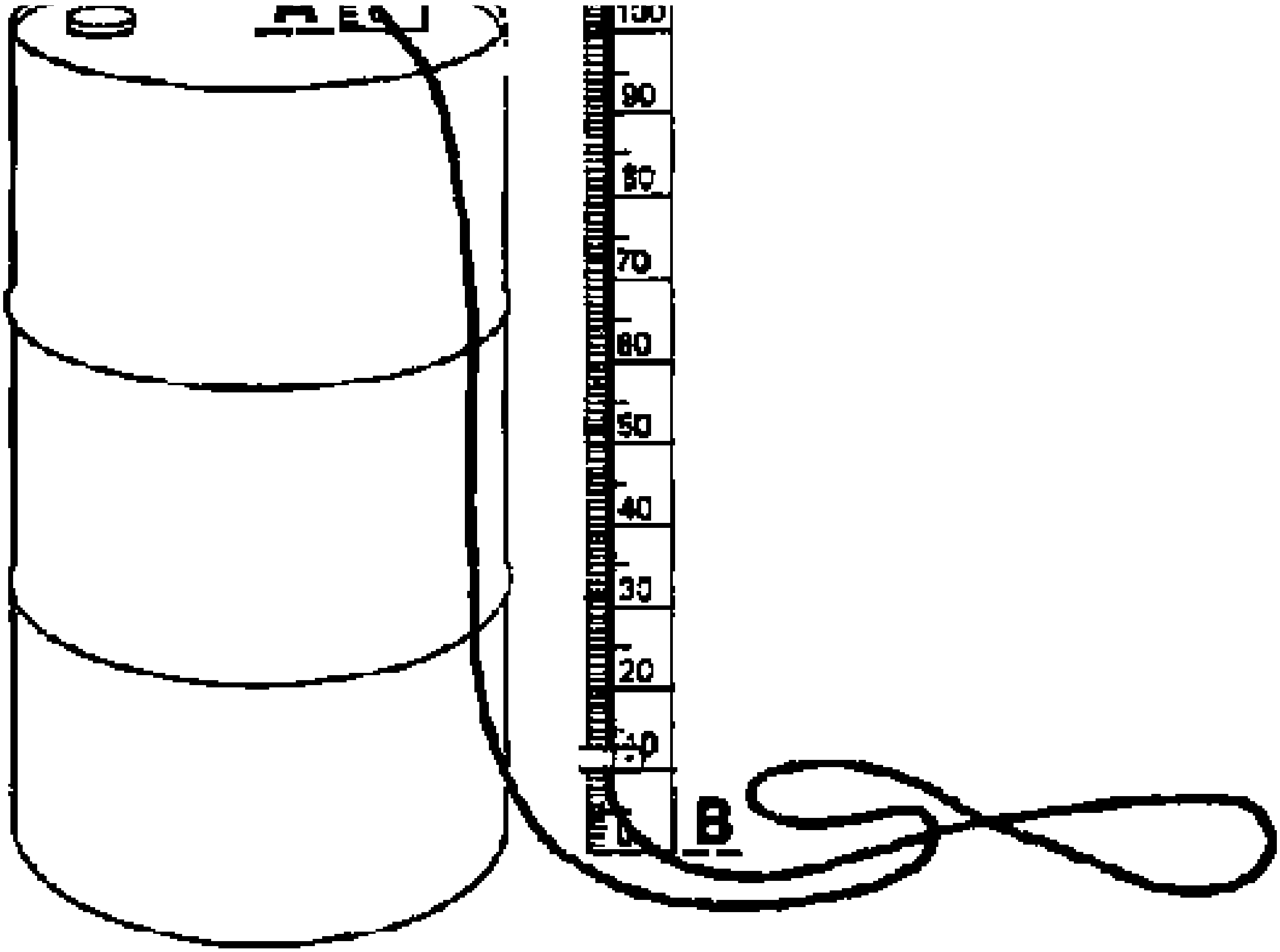
**Fig 44 Graduation of a staff**



tube
staff
graduation
in cm
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

**Fig. 45 Determination of difference in elevation between two close points**






In our example (see Fig. 45):

Measured
reading on staff A: 0.50 m
reading on staff B: 1.50 m

Answer
Difference in elevation between A and B =
reading A - reading B = 0.50 - 1.50 = -1.00 m

In this case, the reading on staff B is higher than the reading on staff A; the result of the subtraction is negative which means that point B is below point A.

If the reading on staff B is lower than the reading on staff A, the result of the subtraction is positive which means that point B is above point A.

B. Measuring the difference in elevation between two distant points

Suppose the difference in elevation between two points A and B has to be measured, and A and B are more than 10 metres apart.

The flexible tube of the instrument is too short to take only one measurement. Several steps are needed.

Step 1

In between points A and B, pegs are placed at intervals slightly less than 10 metres (see pegs C, D and E in Fig. 46a).

**Fig. 46a Determination of difference in elevation, Step 1**

Step 2

The back staff is set near peg A, and the front staff near peg C (see Fig. 46b).

**Fig. 46b Determination of difference in elevation, Step 2**

A reading is made on both staffs and the results written down in a book. The back reading in one column, the front reading in another column.

| Between pegs | Back Reading (m) | Front Reading (m) |
|---|---|---|
| A and C | 0.75 | 1.25 |

Step 3

Both men move. The back staff is set near peg C and the front staff is set near peg D. Again, readings are made and entered in the book (see Fig. 46c).

**Fig. 46c Determination of difference in elevation, Step 3**

The procedure is repeated until the front staff is set near peg B and the back staff is set near the last intermediate peg (E in our example). The last readings are made and written down in the book.

EXAMPLE:

| **Between pegs** | **Back Reading (m)** | **Front Reading (m)** |
|---|---|---|
| A and C | 0.75 | 1.25 |
| C and D | 0.52 | 1.48 |
| D and E | 1.23 | 0.77 |
| E and B | 0.41 | 1.59 |
| Total | 2.91 | 5.09 |

Step 4

The difference in elevation between point A and point B is given by the formula:

| Difference in elevation = sum of the back readings - sum of the front readings |
|---|

In our example:

Measured
sum back readings = 2.91 m
sum front readings = 5.09 m

Answer

difference in elevation between A and B
= 2.91 m - 5.09 m = - 2.18 m

The negative result means that point B is below point A. A positive result would indicate that point B is above point A.

# 6.4 The Hand Level

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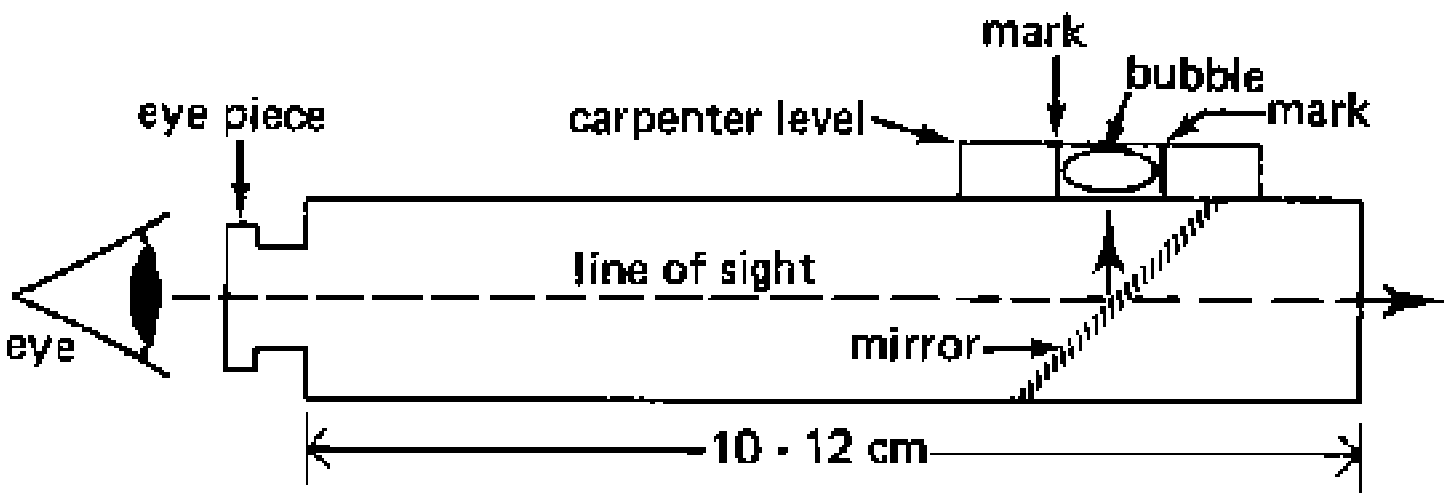
## 6.4.1 Description

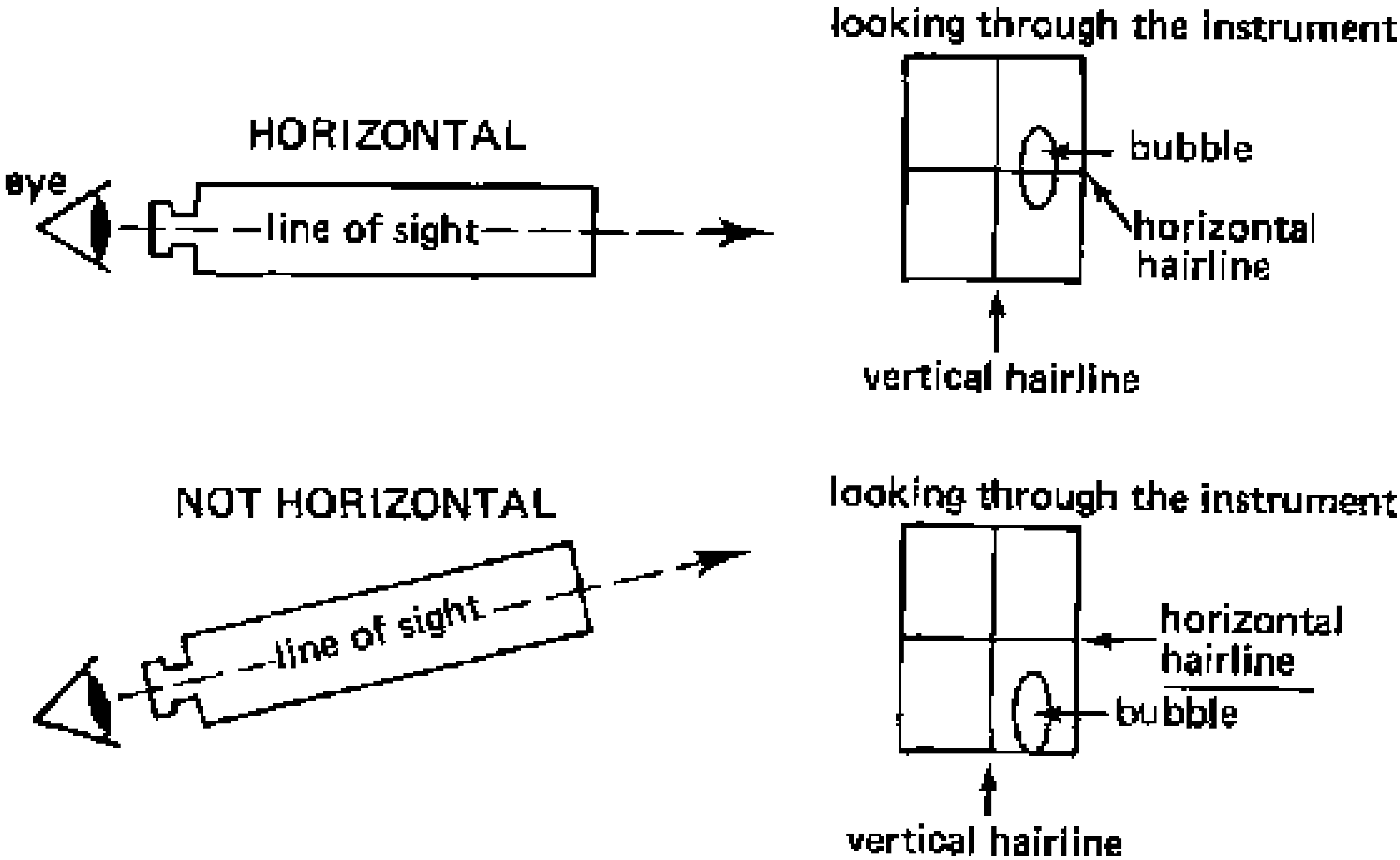
The hand level consists of a 10-12 cm long tube with an eye piece at one end and two hair lines (one horizontal and the other vertical) at the other end. Attached to the tube is a small carpenter level (see Fig. 47).

**Fig. 47 A hand level**




When the operator looks through the eye-piece, the mirror inside the tube, reflects (on the right hand side) the position of the bubble of the carpenter level. The instrument is made in such a way that when the bubble is in sight on the horizontal hair line, the instrument is horizontal and the line of sight is horizontal (see Fig. 48).

**Fig. 48 Use of the hand level**




For greater stability the instrument can be supported by a forked bush pole, with a metal plate attached to the bottom. This assures that the instrument is always at the same height above the ground surface.

## 6.4.2 Use of the hand level

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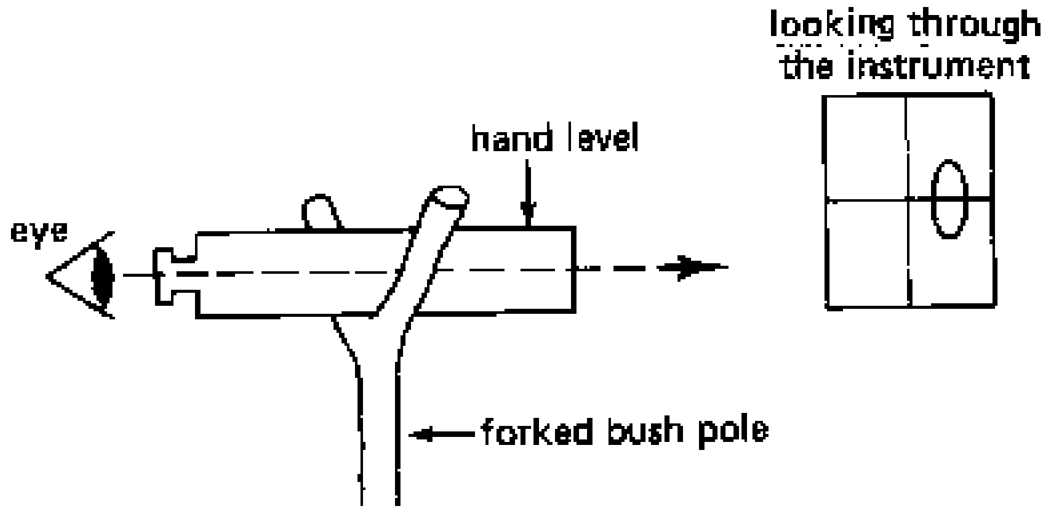
The hand level can be used to set out contour lines and to measure the difference in elevation between two points.

### 6.4.2.1 Setting out contour lines

Step 1

The forked pole is set on the starting point. The hand level is placed on the crotch of the forked pole and tilted slowly until the bubble is seen at the horizontal hair line (see Fig. 49a).

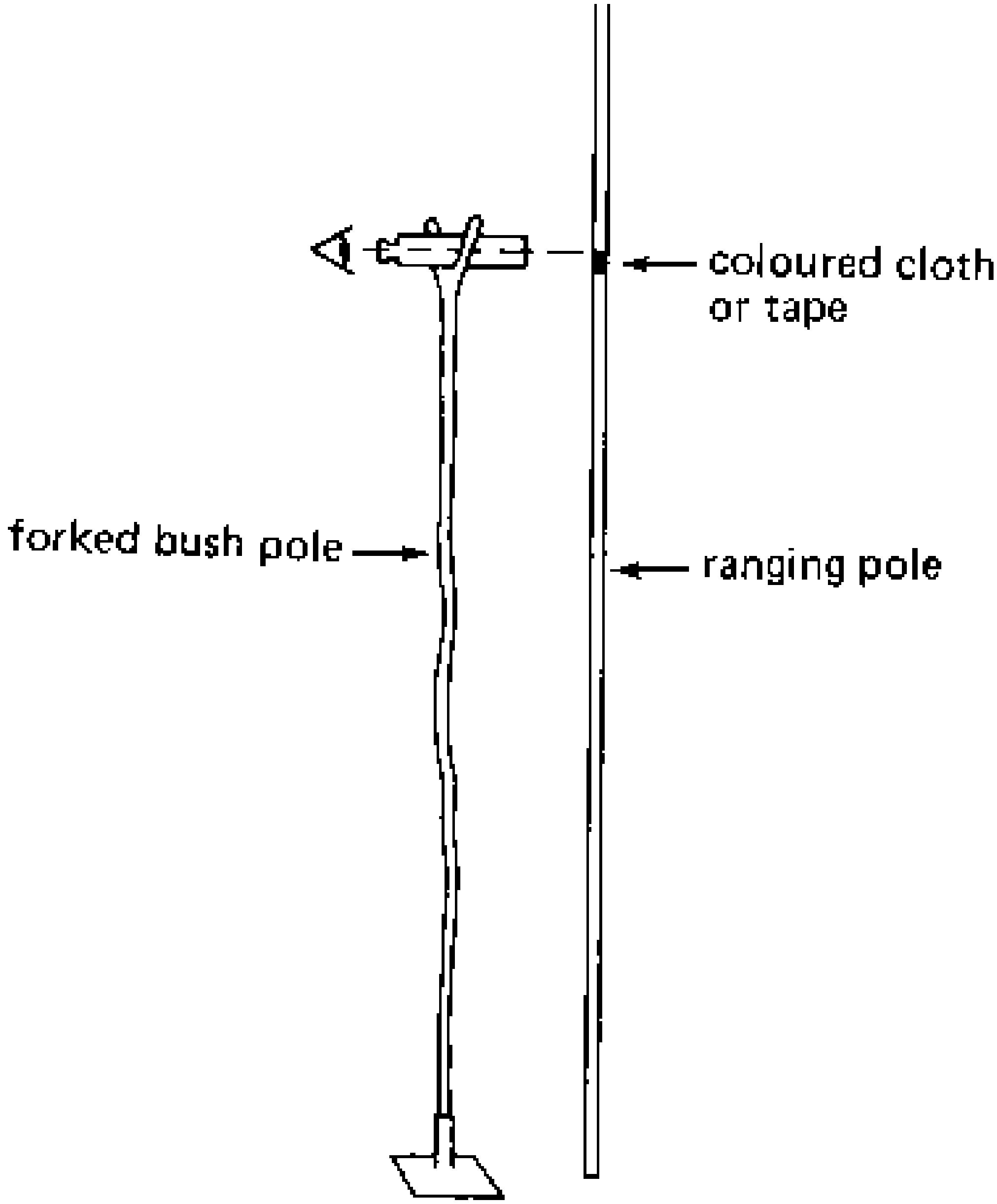
**Fig. 49a Setting out a contour line, Step 1**




Step 2

A ranging pole is brought close to the hand level, and placed on the ground at the same elevation as the starting point (see Fig. 49b).

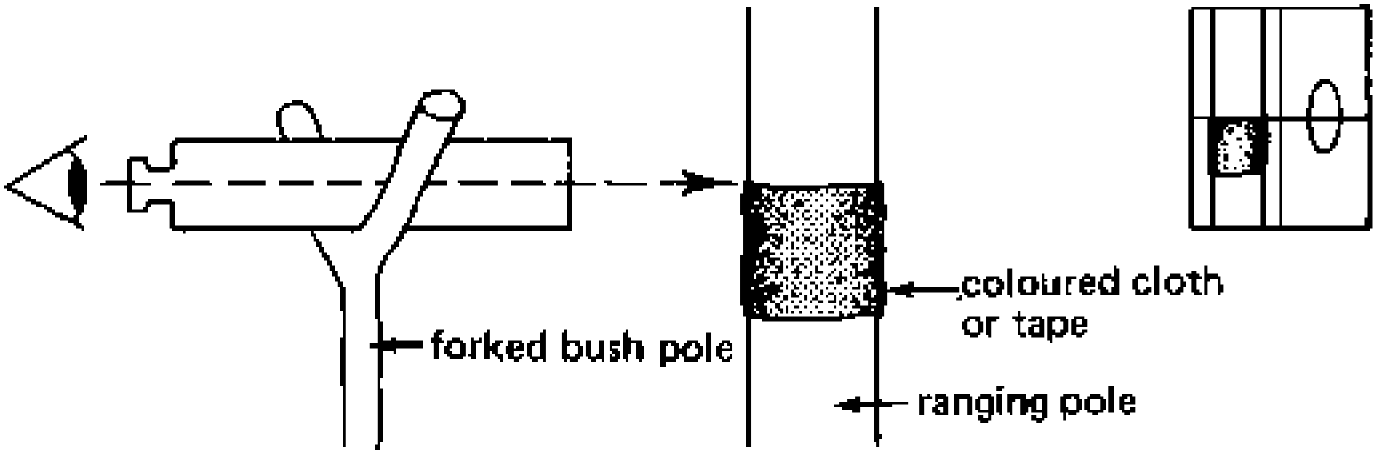
**Fig. 49b Setting out a contour line, Step 2**




Step 3

Looking through the hand level, the elevation of the horizontal hairline is marked on the ranging pole. This can be done by tying a piece of coloured cloth around the pole, or with some coloured tape. The top side of the cloth or tape should coincide with the horizontal hairline of the instrument (see Fig. 49c).

**Fig. 49c Setting out a contour line, Step 3**




Step 4

The ranging pole is placed about 10 to 15 metres away from the instrument in the general direction of the contour line. The assistant moves with the ranging pole slowly up and down the slope. The observer sights the pole and follows it by rotating the instrument, holding the bubble on the horizontal hairline. When the top of the ranging mark on the pole coincides with the horizontal hairline, the ranging pole is set on a point (B) which is exactly at the same elevation as the starting point (A) (see Fig. 49d). This point is marked with a peg.

**Fig. 49d Setting out a contour line, Step 4**

Step 5

The same process is repeated, this time starting from peg (B), to find the next point (C) of the contour line.

REMARK: The hand level can only be used with accuracy up to a **distance** of about 15 m. Vision will become poor beyond this distance and accuracy cannot be maintained.

### 6.4.2.2 Measuring differences in elevation

A. Measuring the difference in elevation between two close points

The difference in elevation between two close points (A and B) can be measured with a hand level and a graduated staff. The procedure to follow is:

Step 1

The observer takes a position about half way between the two points A and B, that are less than 25 m apart, Over this distance the hand level can be used with reasonable accuracy (see Fig. 50a).

Step 2

The assistant places the staff at point A. The observer sights the staff at point A and moves the instrument to the horizontal position. The value indicated by the horizontal hairline is read and written down by the observer (see Fig. 50b). This reading is called a back reading.

**Fig. 50a Measuring the difference in elevation, Step 1**

**Fig. 50b Measuring the difference in elevation, Step 2**

Step 3

The assistant walks to point B and places the staff on point B. The observer turns around, the bush pole remaining in the same spot, and sights the staff at point B. After moving the instrument to the horizontal position, the value indicated by the horizontal hairline on the staff is read and written down (see Fig. 50c). This reading is called a front **reading.** forward reading 1.38 m

**Fig. 50c Measuring the difference in elevation, Step 3**

Step 4

The difference in elevation between point A and point B can be calculated with the formula:

| |
|---|
| Difference in elevation between A and B = reading on A - reading on B<br>= back reading - front reading |

In our example:

Measured
reading on A (back reading): 1.62 m
reading on B (front reading): 1.38 m

Answer
Difference in elevation = 1.62 - 1.38 = + 0.24 m

The result is positive, point B is above point A. A negative result would mean that point B is below point A.

B. Measuring the difference in elevation between two distant points When points A and B are further apart than 25 m, the procedure to follow is:

Step 1

Place pegs at points A and B and at intervals of 25 m or less in between points A and B. See example Fig. 51.

**Fig. 51 Measuring the difference in elevation between two distant points A and B**

Step 2

The observer takes up a position between A and C and measures the difference in elevation between point A (near peg A) and point C (near point C) as described in the previous section.

Step 3

The observer takes up a position between point C and point D. The assistant turns the staff at point C in the direction of point D. The staff should stay in the same position and not be lifted.

Step 4

Measure the difference in elevation between points C and D as described in the previous section. Continue until the difference in elevation between the last intermediate point and B has been determined.

Step 5

The difference in elevation between point A and point B is the sum of the differences in elevation between point A, all intermediate points and point B.

Note: The difference in elevation between point A and point B can be found with the formula:

| Difference in elevation between A and B = sum of back readings - sum of front readings |
|---|

EXAMPLE (see Fig. 51):

| **Between points:** | **Back Reading (m)** | **Front Reading (m)** | **Difference in Elevation (m)** |
|---|---|---|---|
| A and C | 0.65 | 1.40 | - 0.75 |
| C and D | 0.20 | 1.25 | - 1.05 |
| D and E | 1.80 | 0.50 | + 1.30 |
| E and F | 1.75 | 0.95 | + 0.80 |
| F and B | 1.37 | 1.24 | + 0.13 |
| Total | 5.77 | 5.34 | + 0.43 |

Difference in elevation between A and B = Sum of back readings - sum of front readings
= 5.77 - 5.34 = + 0.43 m

The difference in elevation is positive, which means that point B is above point A.

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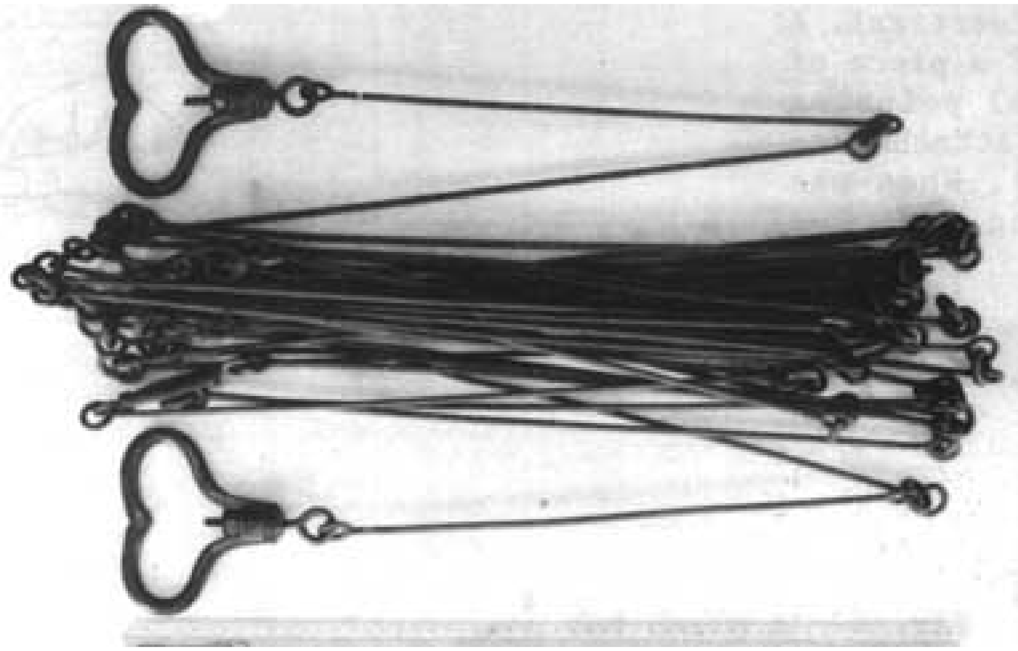
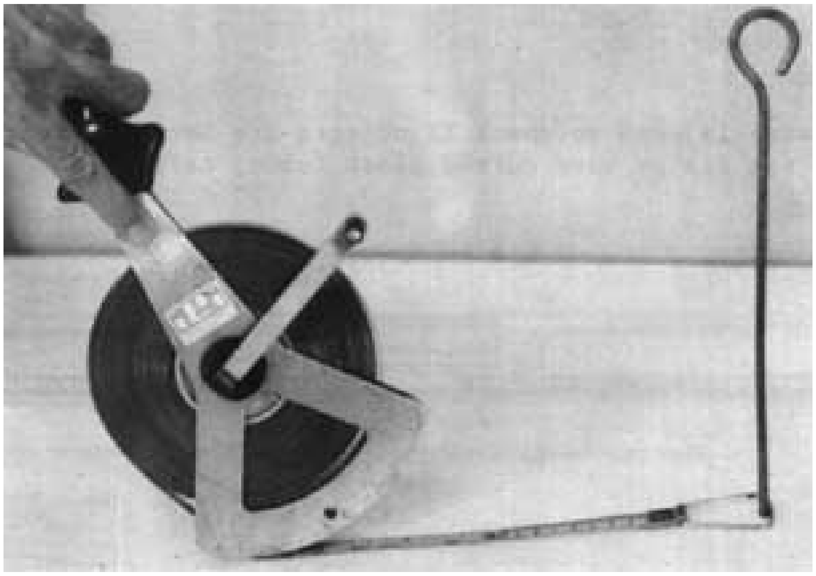
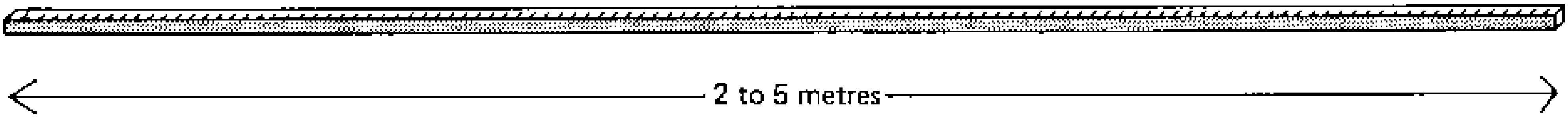
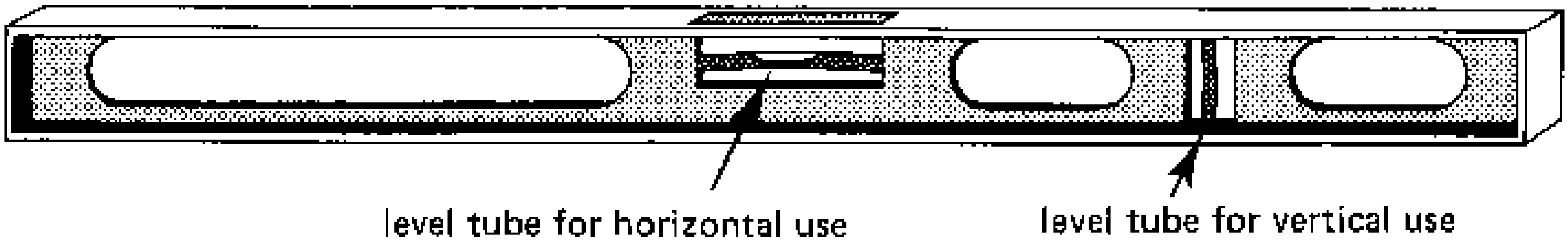
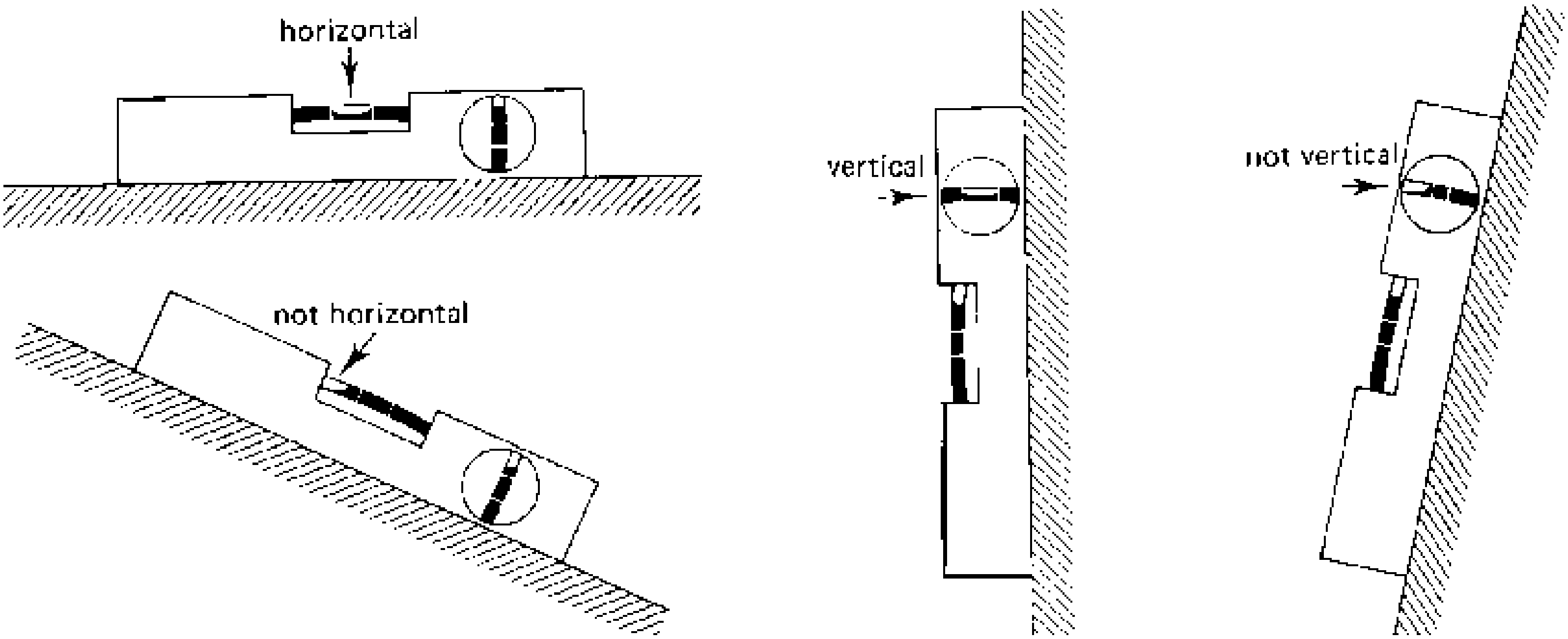
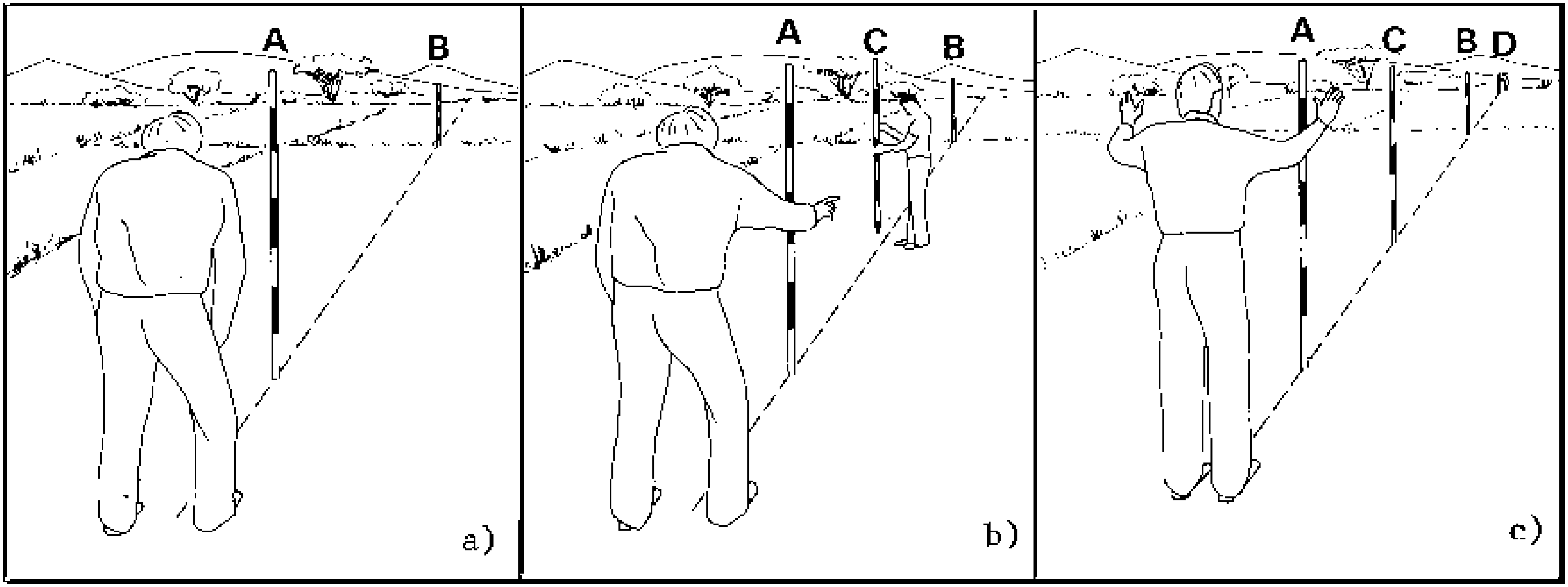


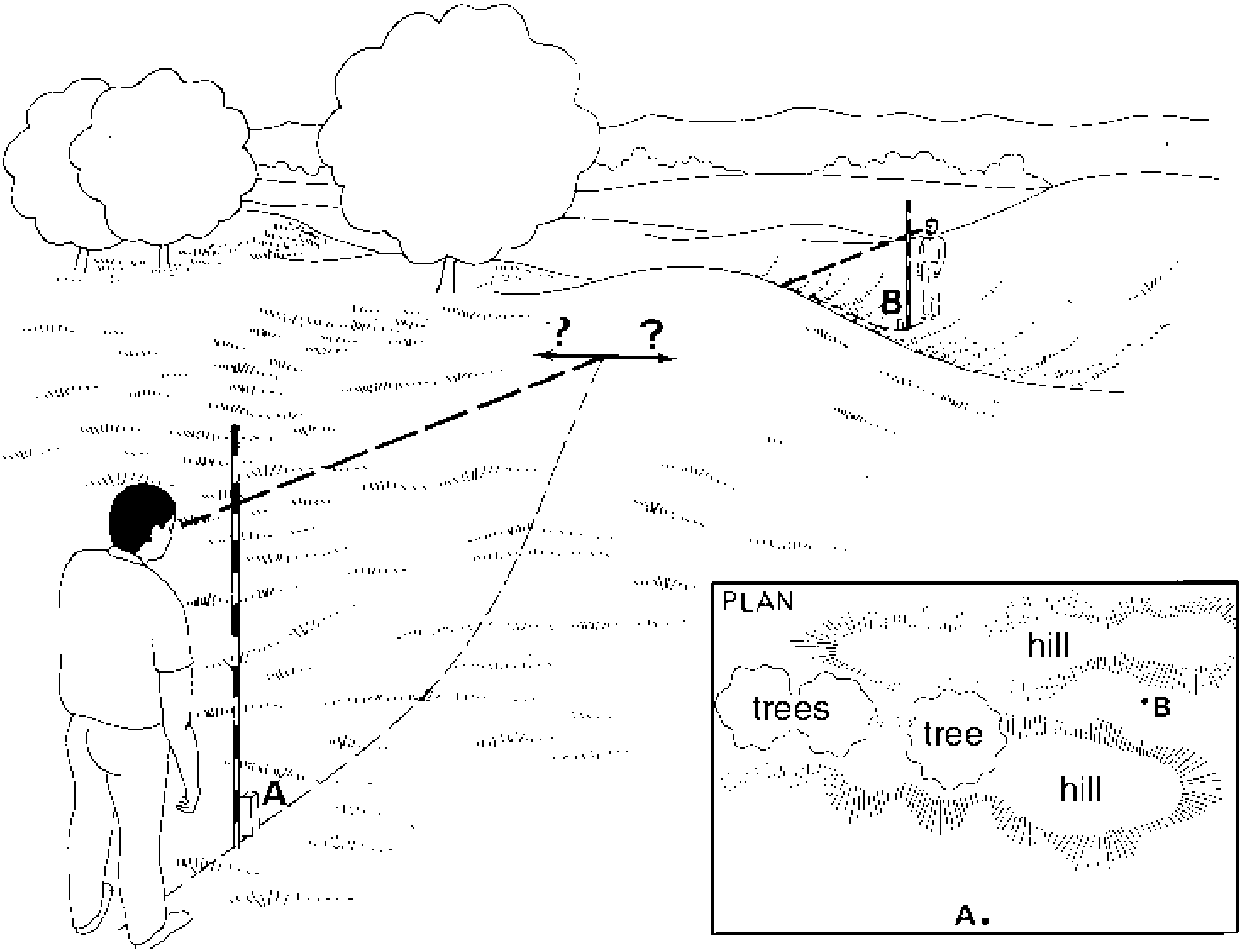


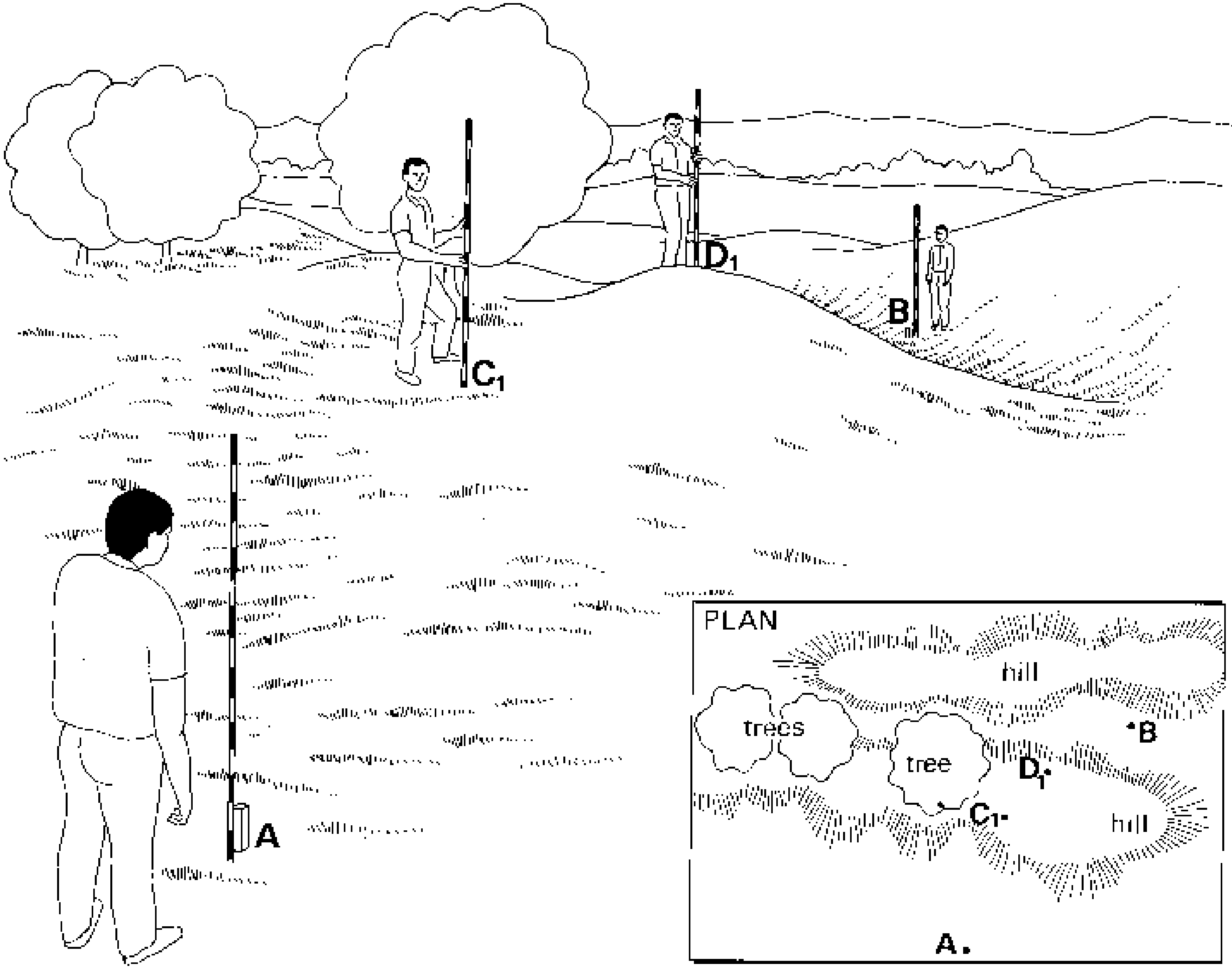

2 to 5 metres

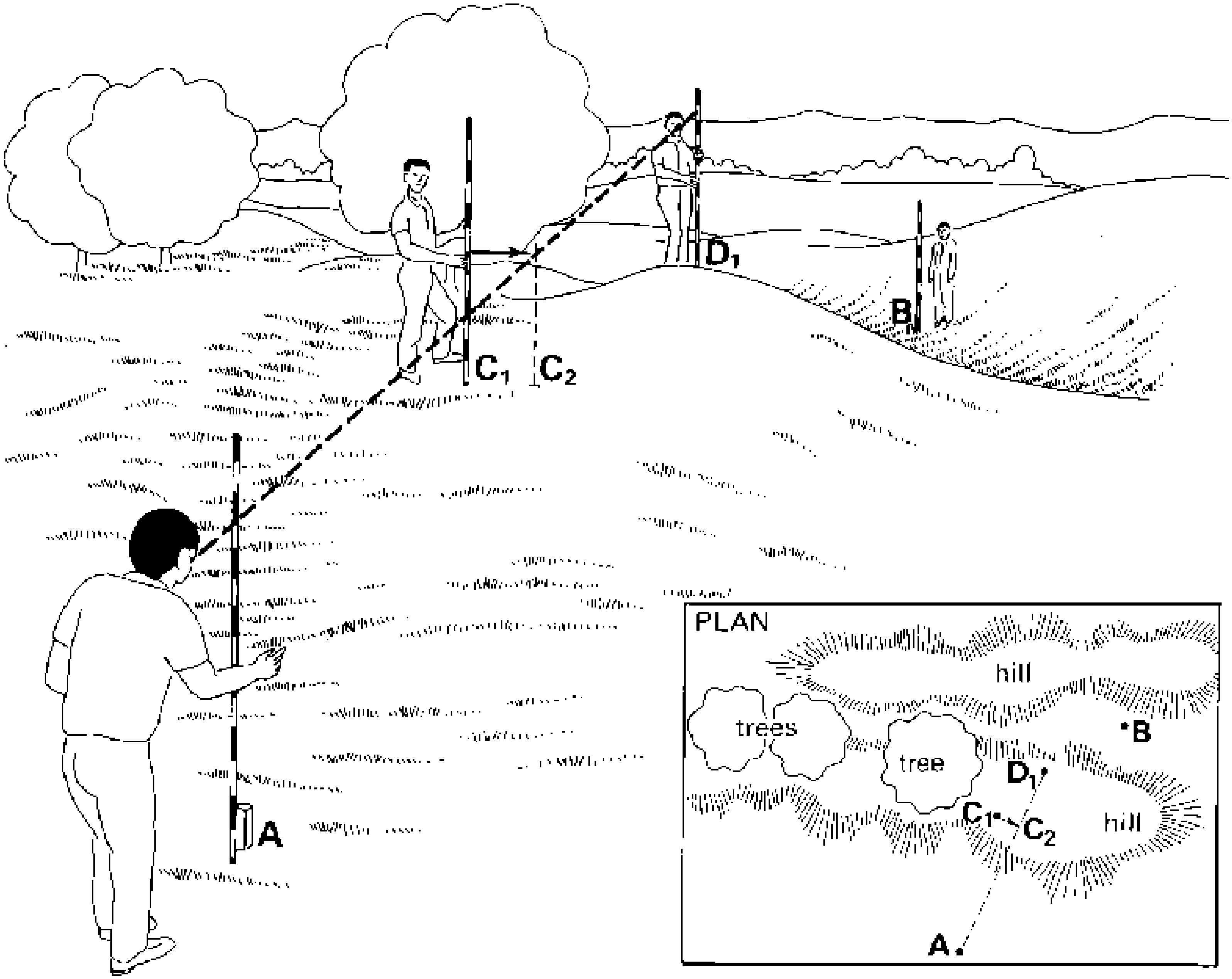

level tube for horizontal use
level tube for vertical use

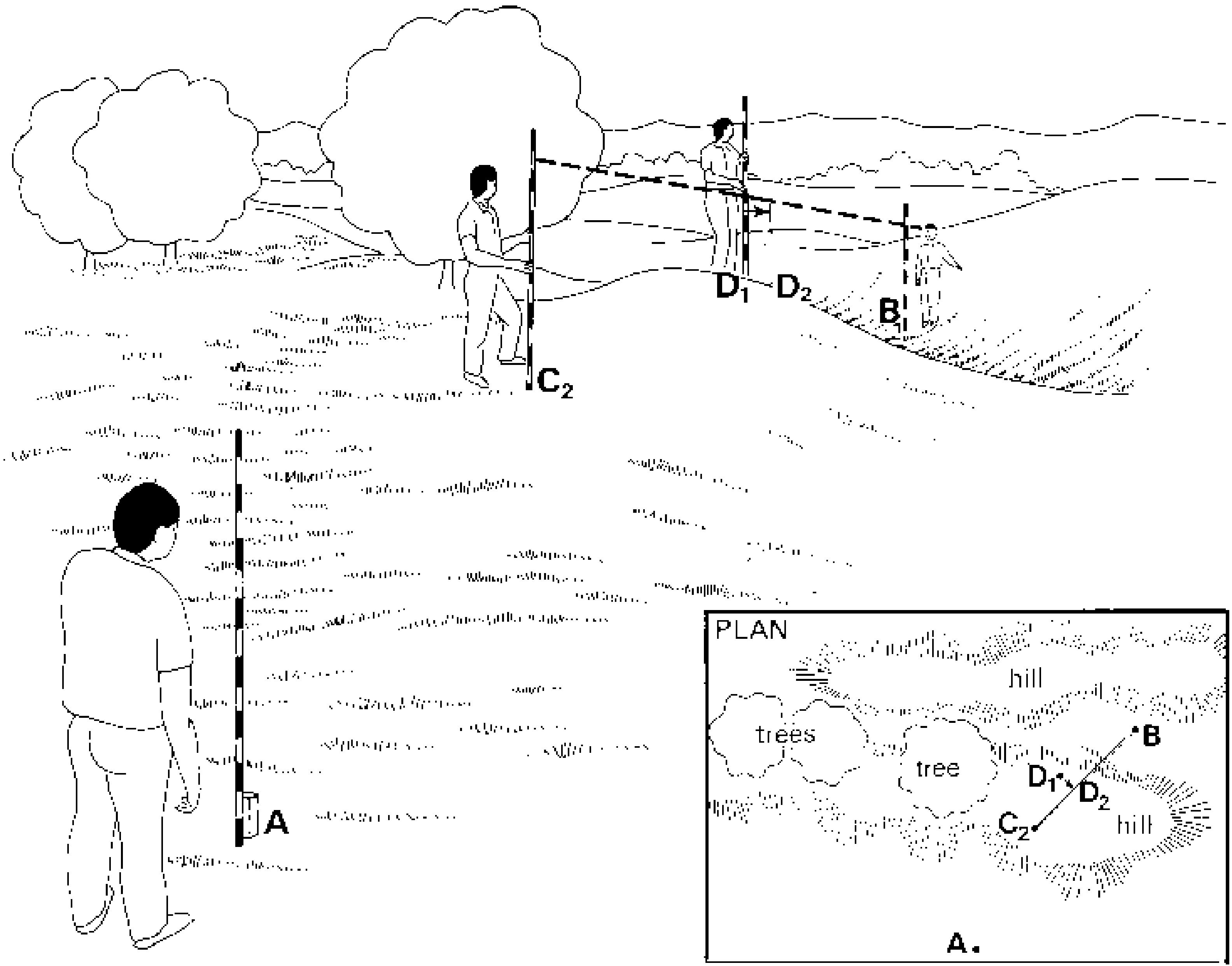

horizontal
not horizontal
vertical
not vertical

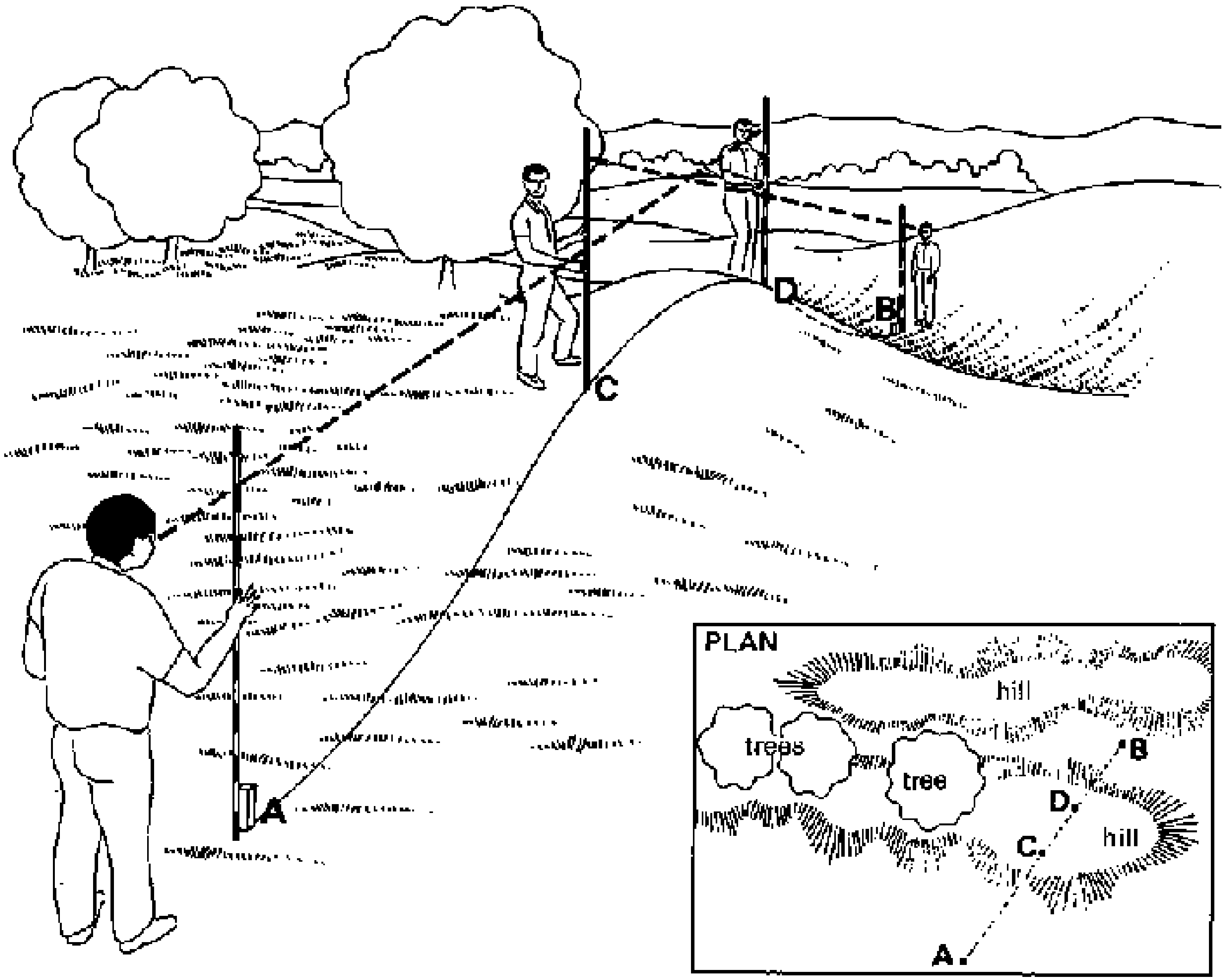

A
B
a)
A
C
B
b)
A
C
B
D
c)

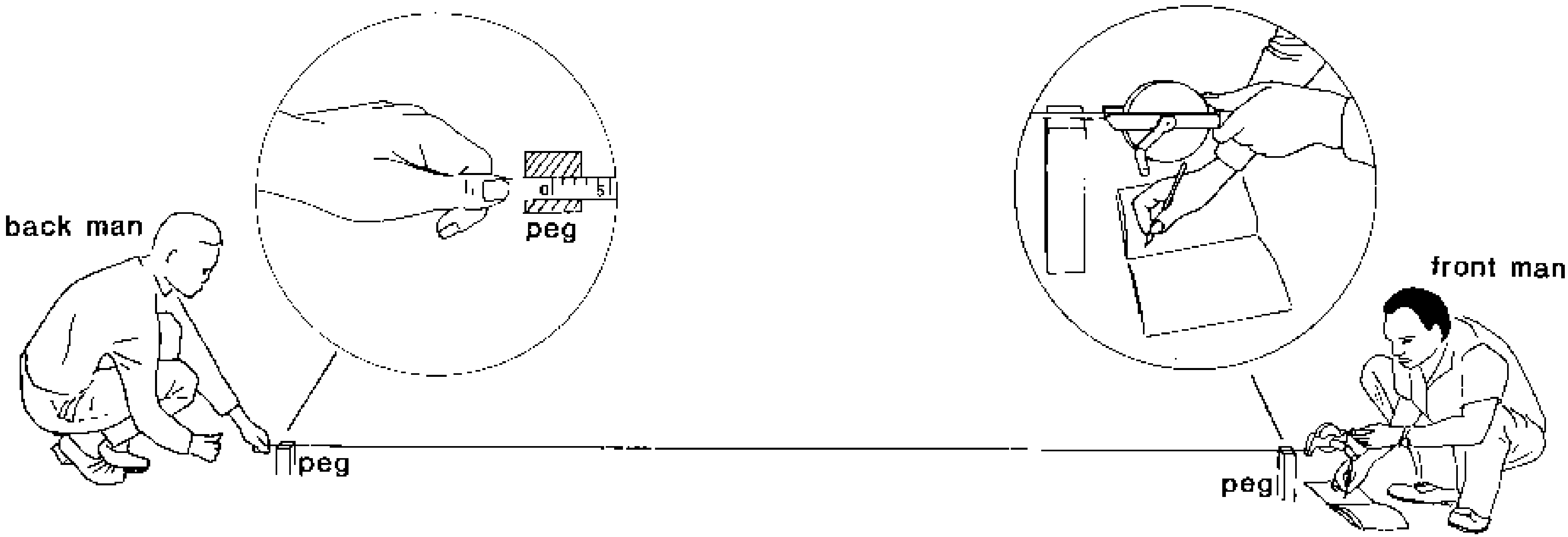

?
?
B
A
PLAN
hill
trees
tree
B
hill
A.

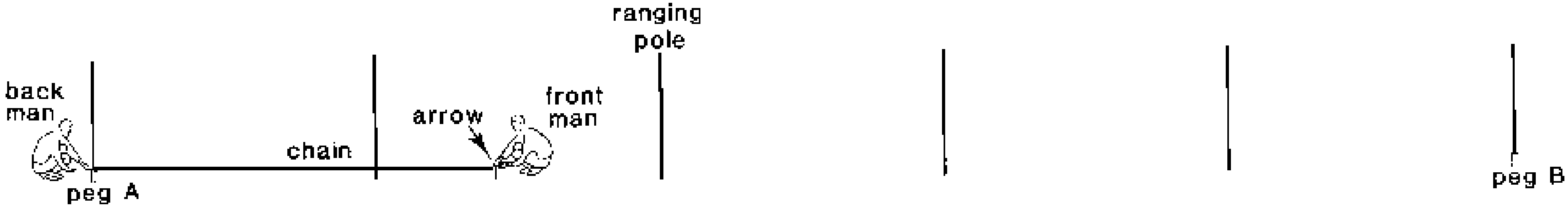

C1
D1
B
A
PLAN
hill
trees
tree
B
D1
C1
hill
A

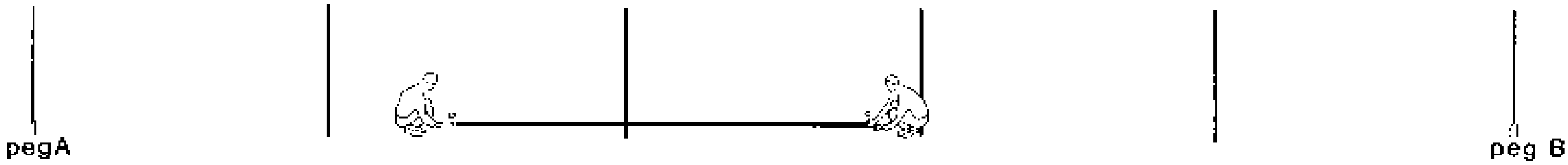

C1
C2
D1
B
A
PLAN
hill
trees
tree
D1
B
C1
C2
hill
A


D1
D2
B
C2
A
PLAN
hill
trees
tree
B
D1
D2
C2
hill
A.

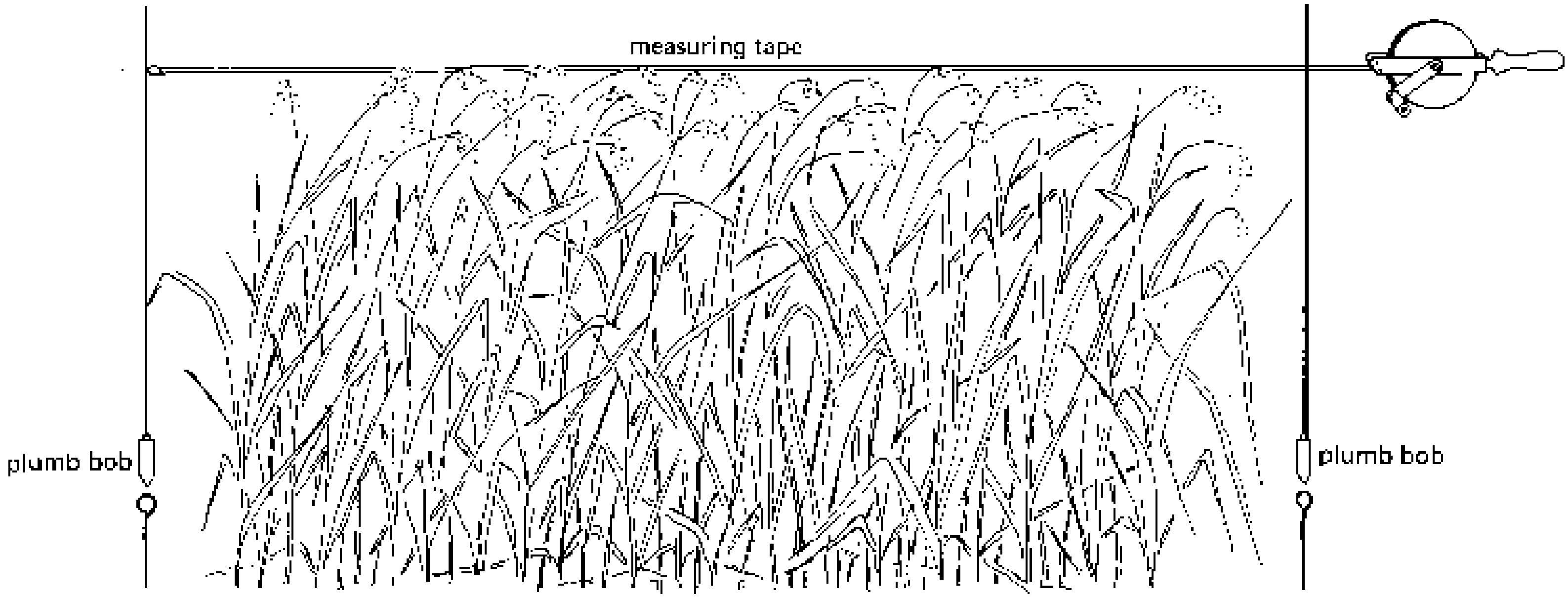

C
D
B
A
PLAN
hill
trees
tree
D.
B
C.
hill
A.


back man
peg
peg
front man
peg
0
5

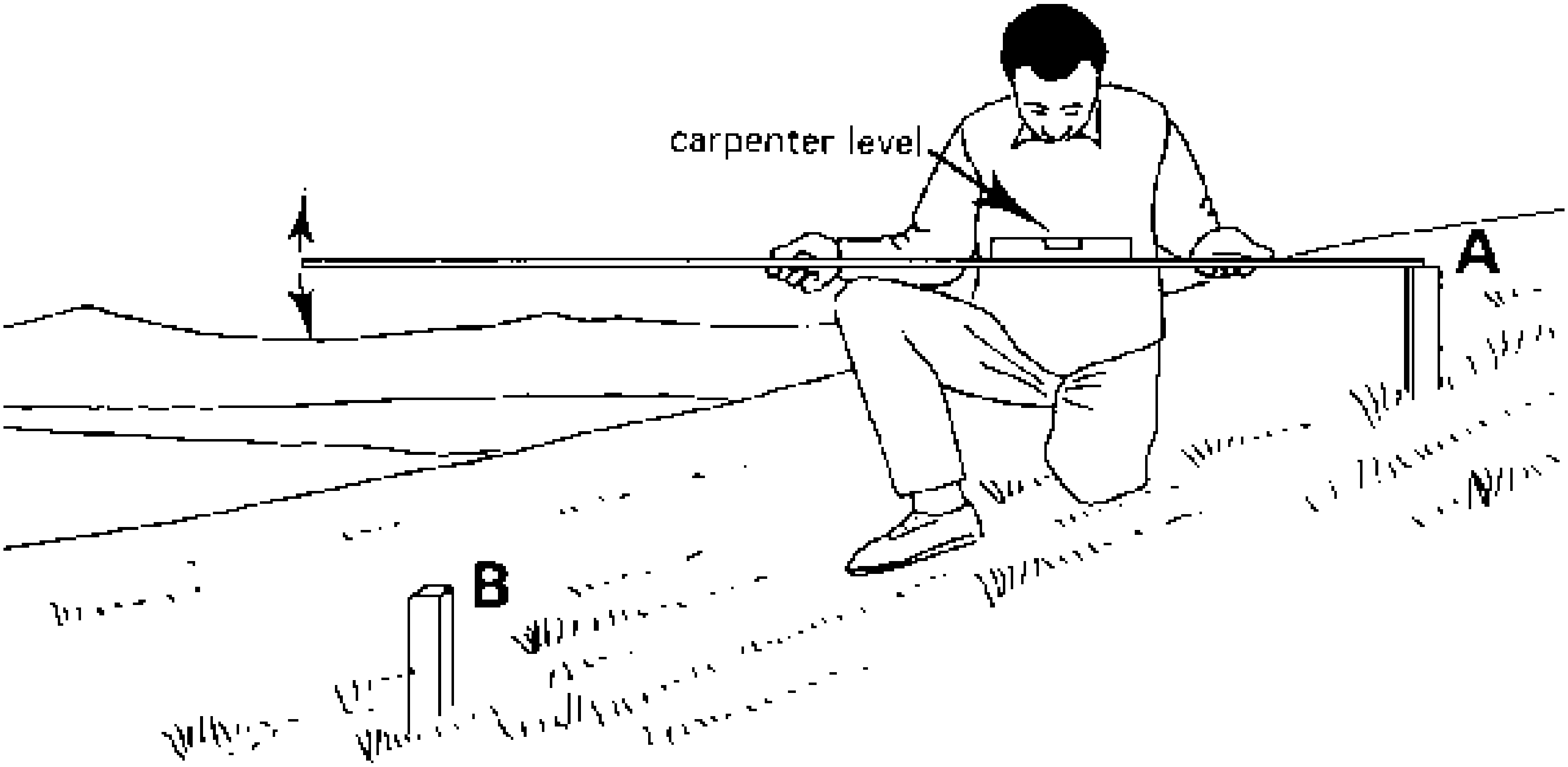

ranging
pole
back
man
arrow
front
man
chain
peg A
peg B

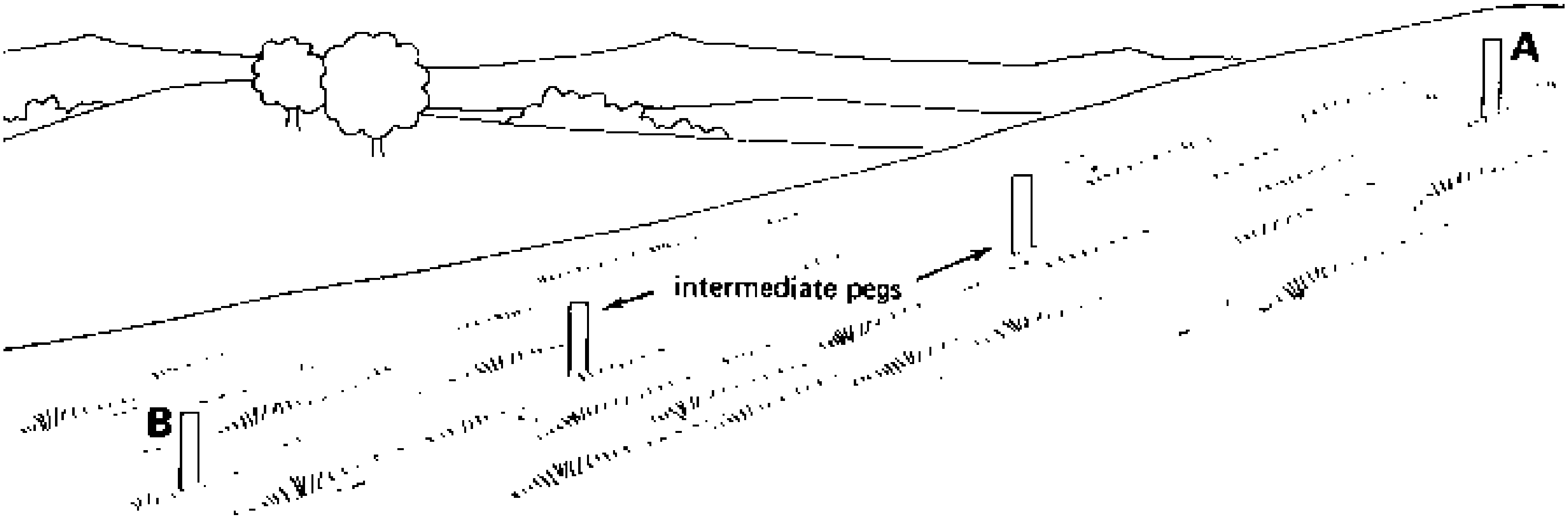

pegA
peg B

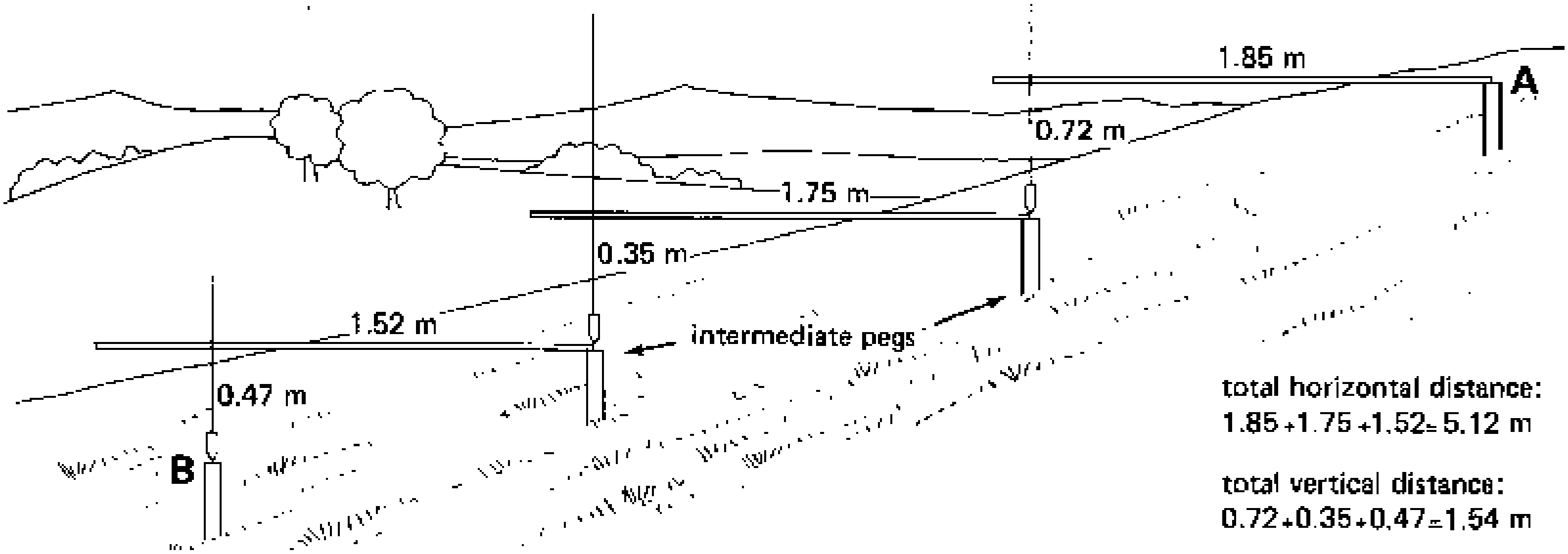

peg A
arrow
arrow
last
arrow
peg B

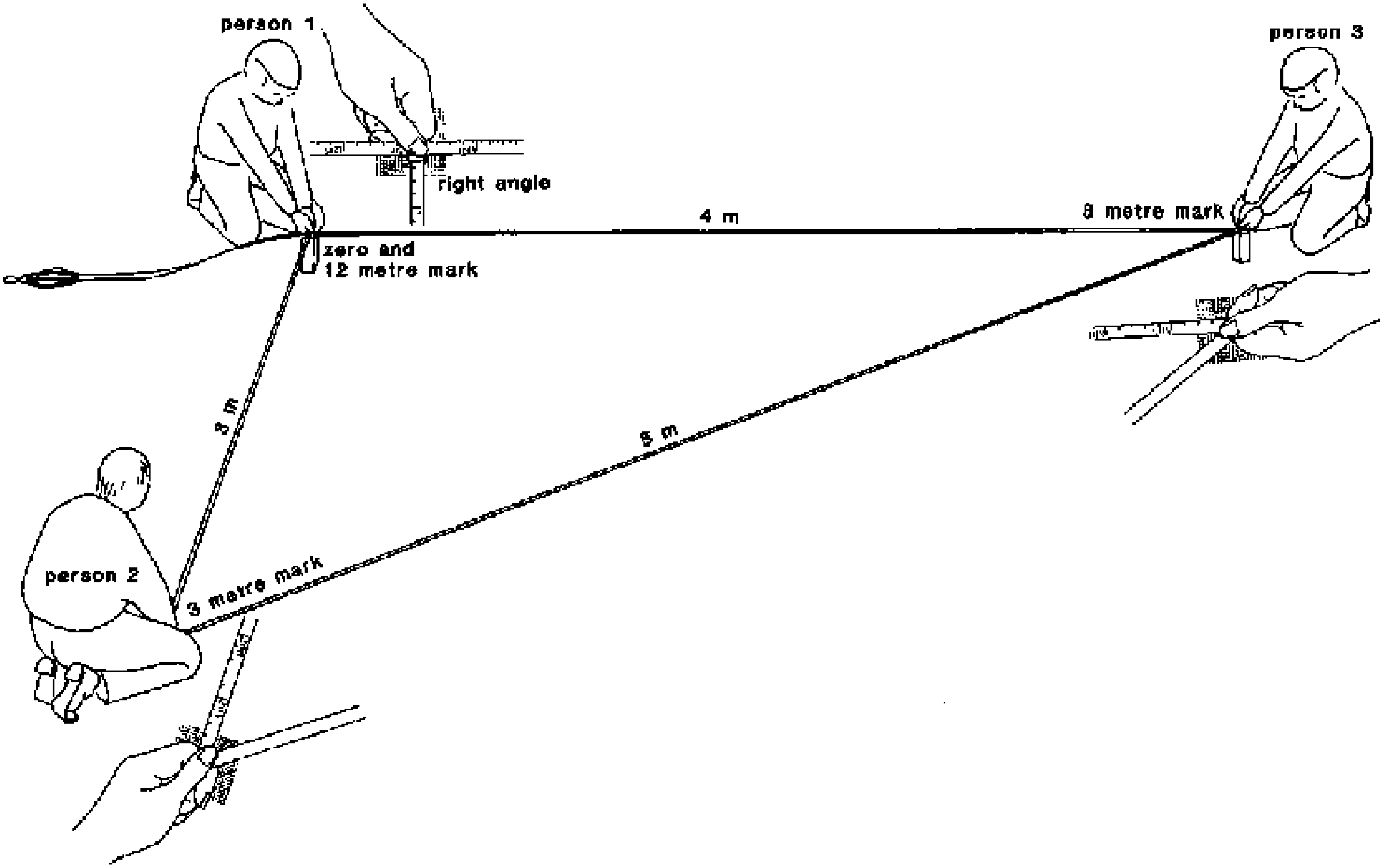

measuring tape
plumb bob
plumb bob

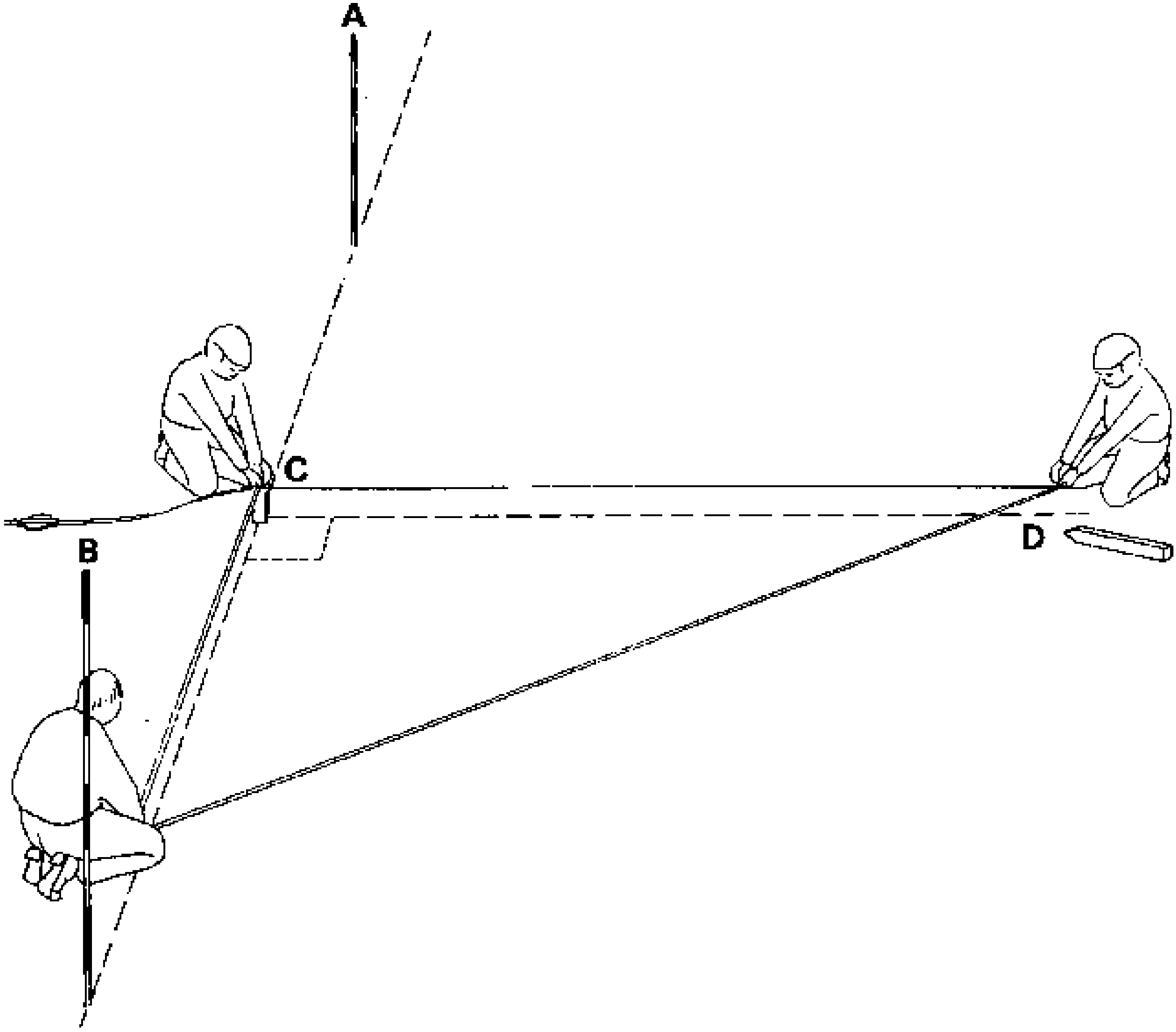

A
B

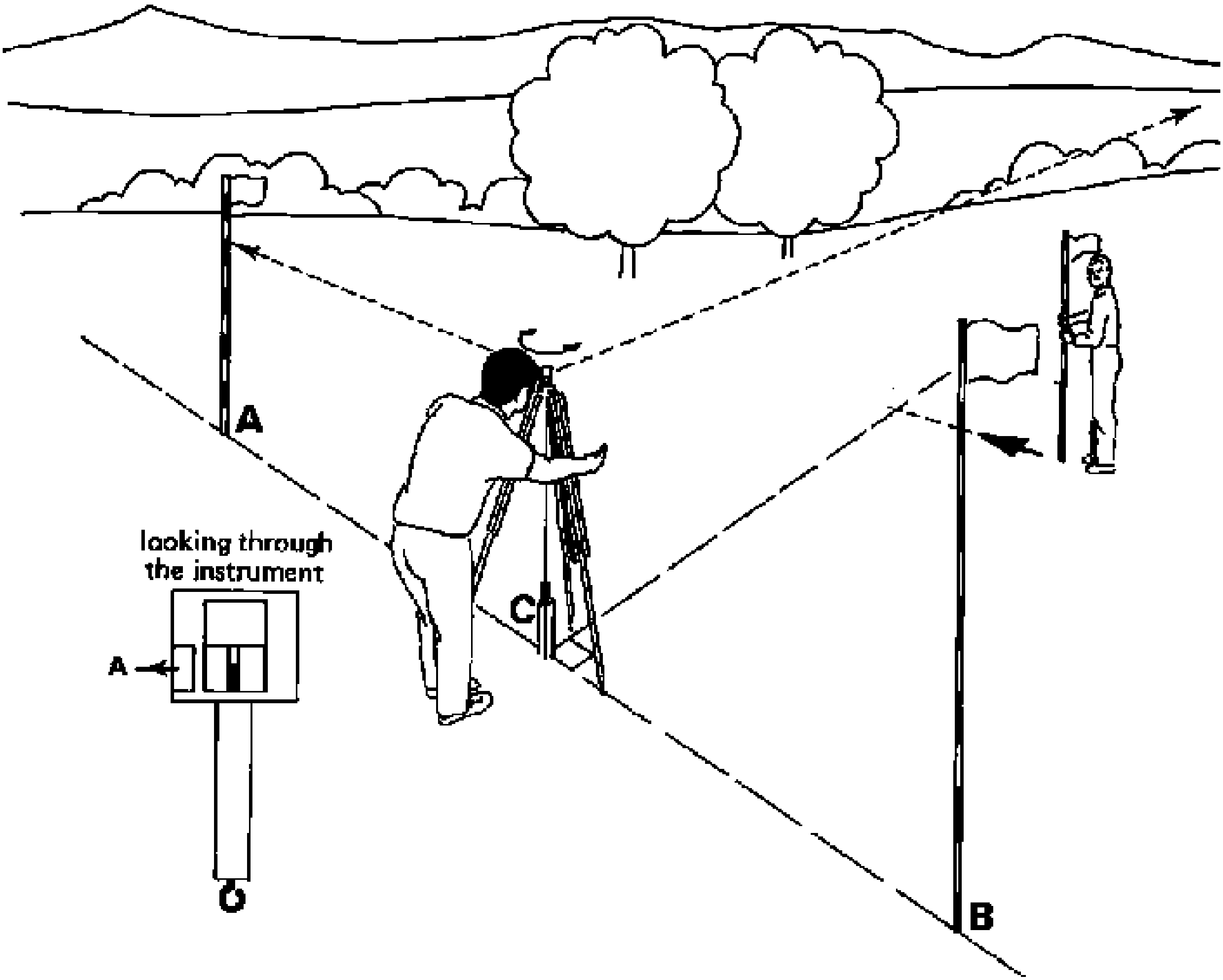

carpenter level
A
B

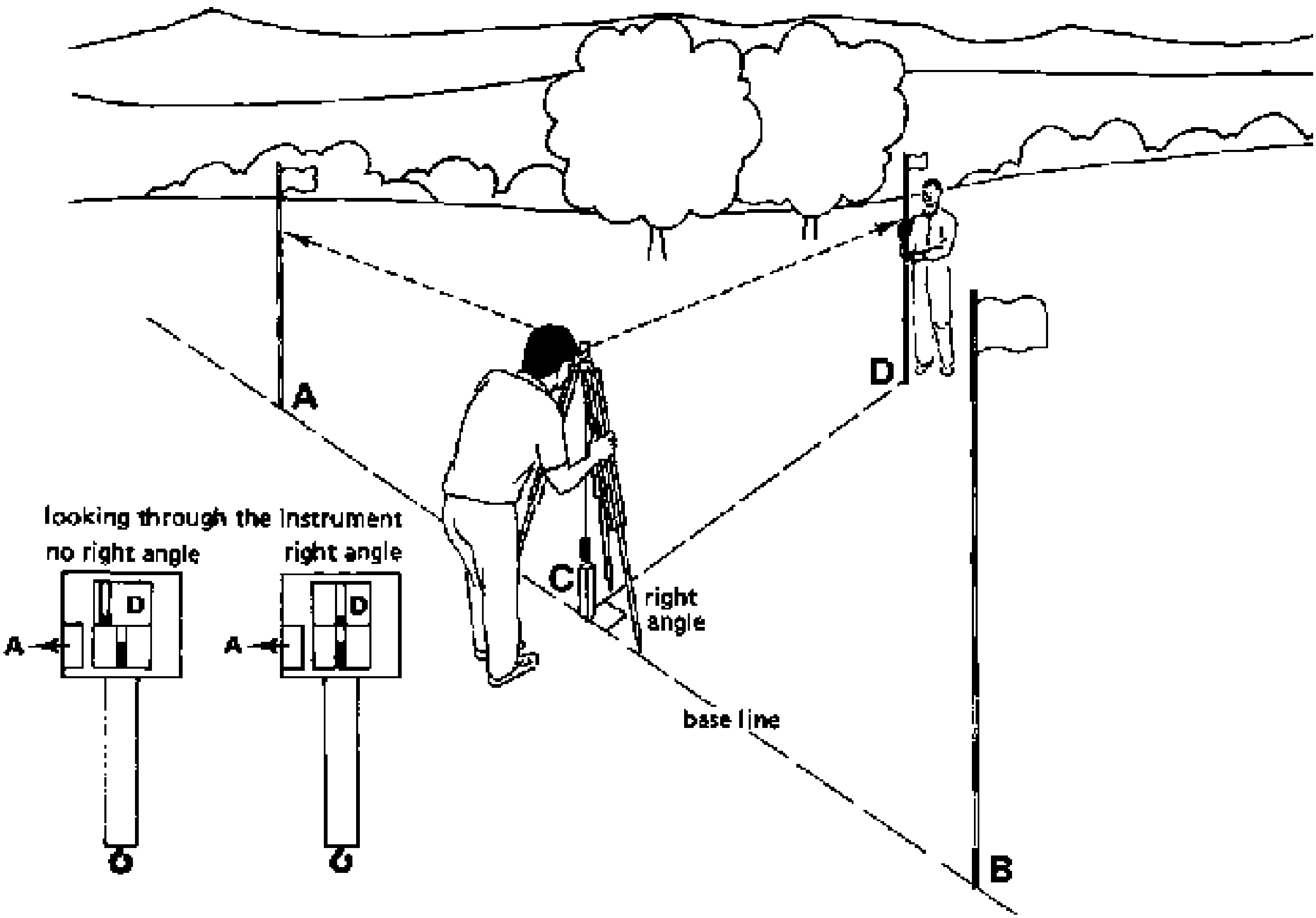

A
intermediate pegs
B


1.85 m
A
0.72 m
1.75 m
0.35 m
1.52 m
intermediate pegs
0.47 m
B
total horizontal distance:
1.85+1.75+1.52=5.12 m
total vertical distance:
0.72+0.35+0.47=1.54 m

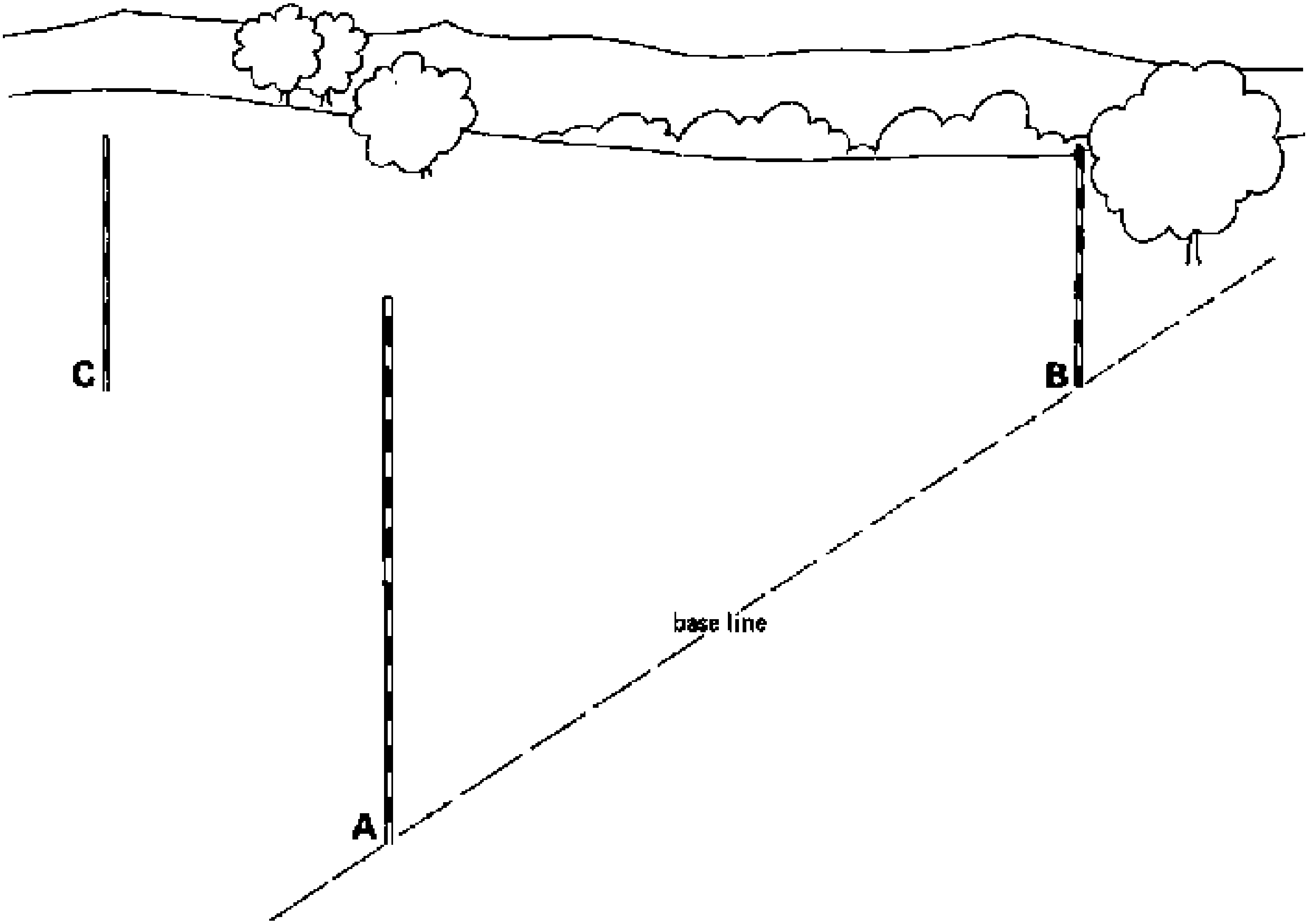

person 1
right angle
person 3
4 m
8 metre mark
zero and
12 metre mark
3 m
5 m
person 2
3 metre mark

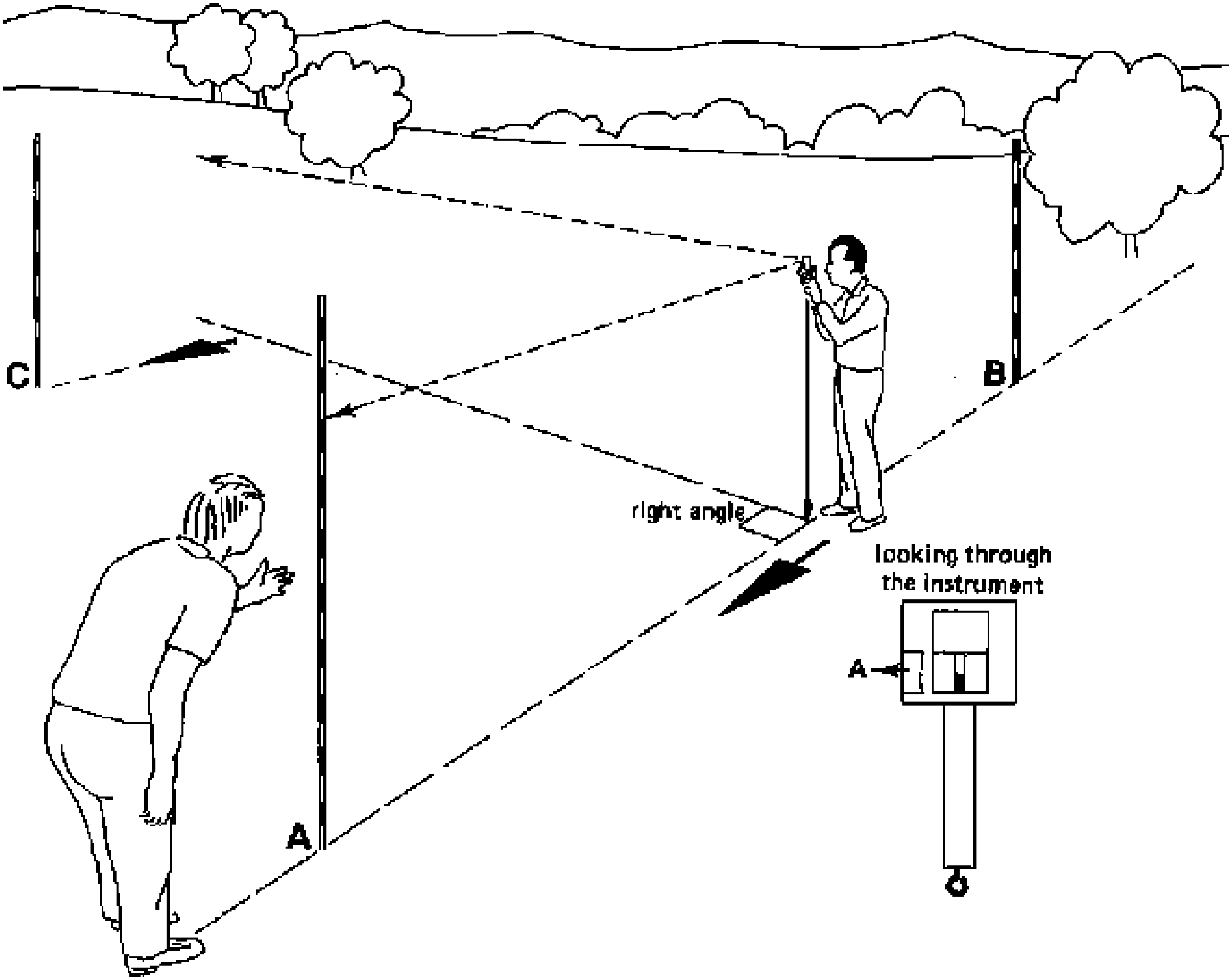

A
C
B
D

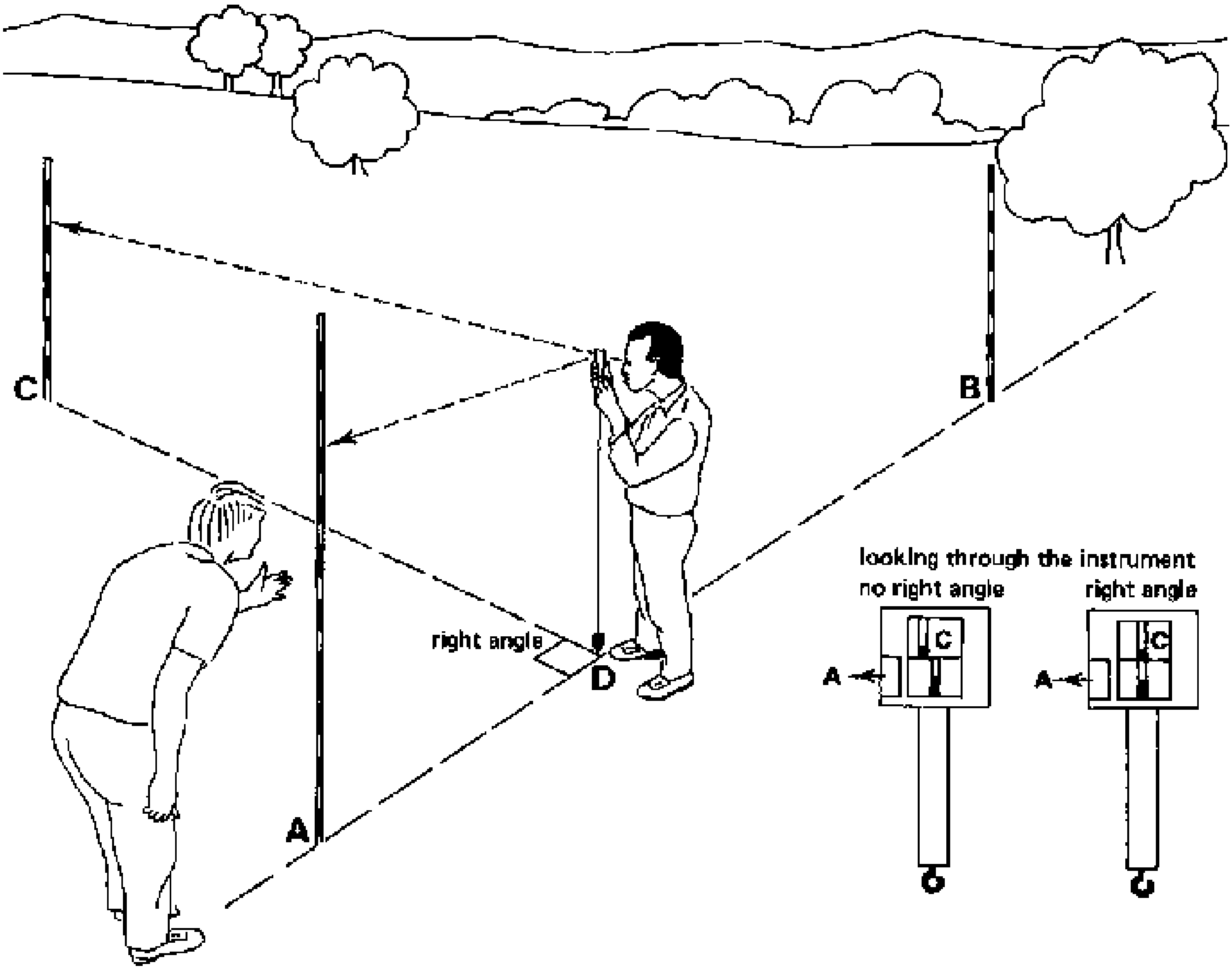

A
C
B
looking through
the instrument
A

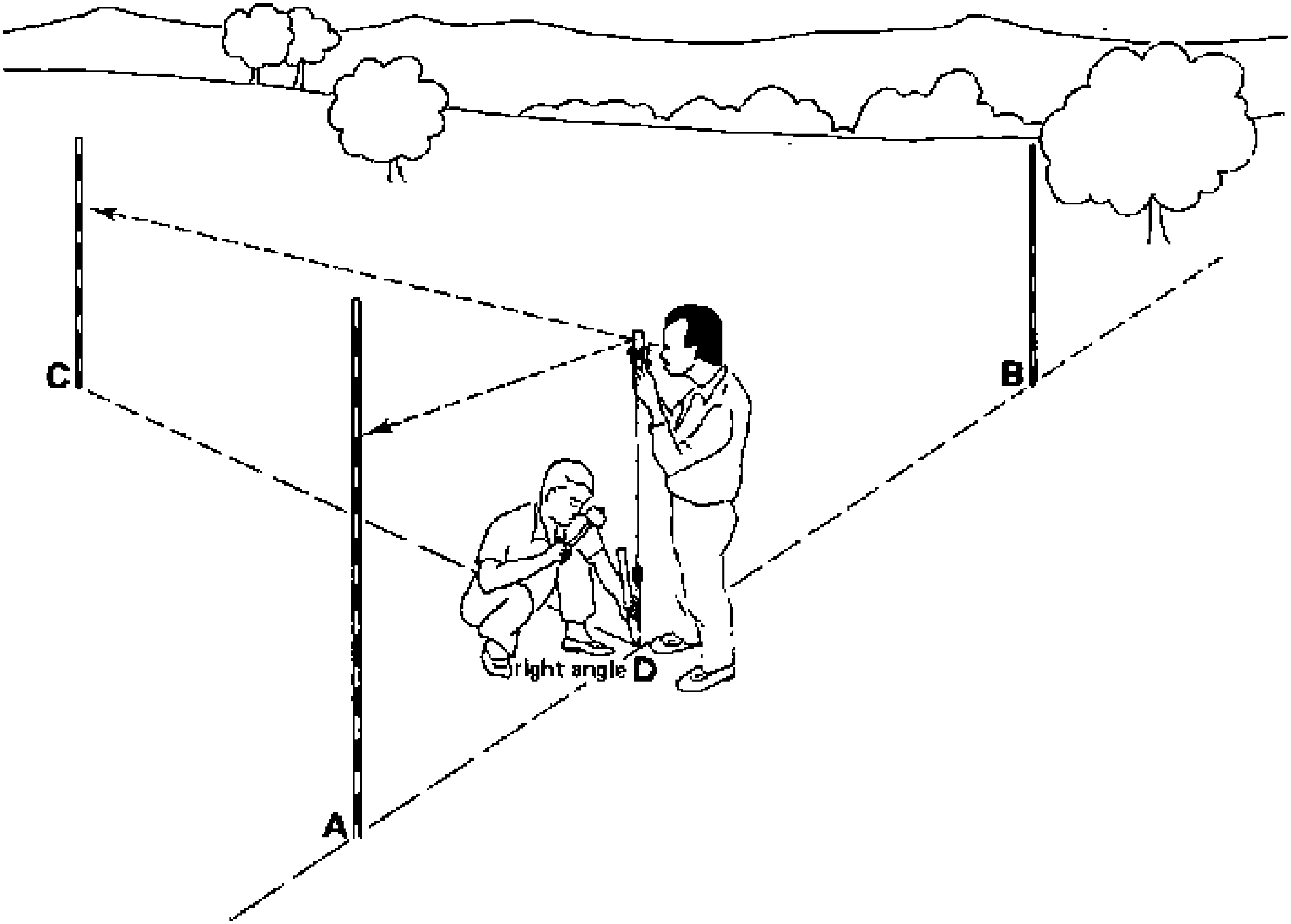


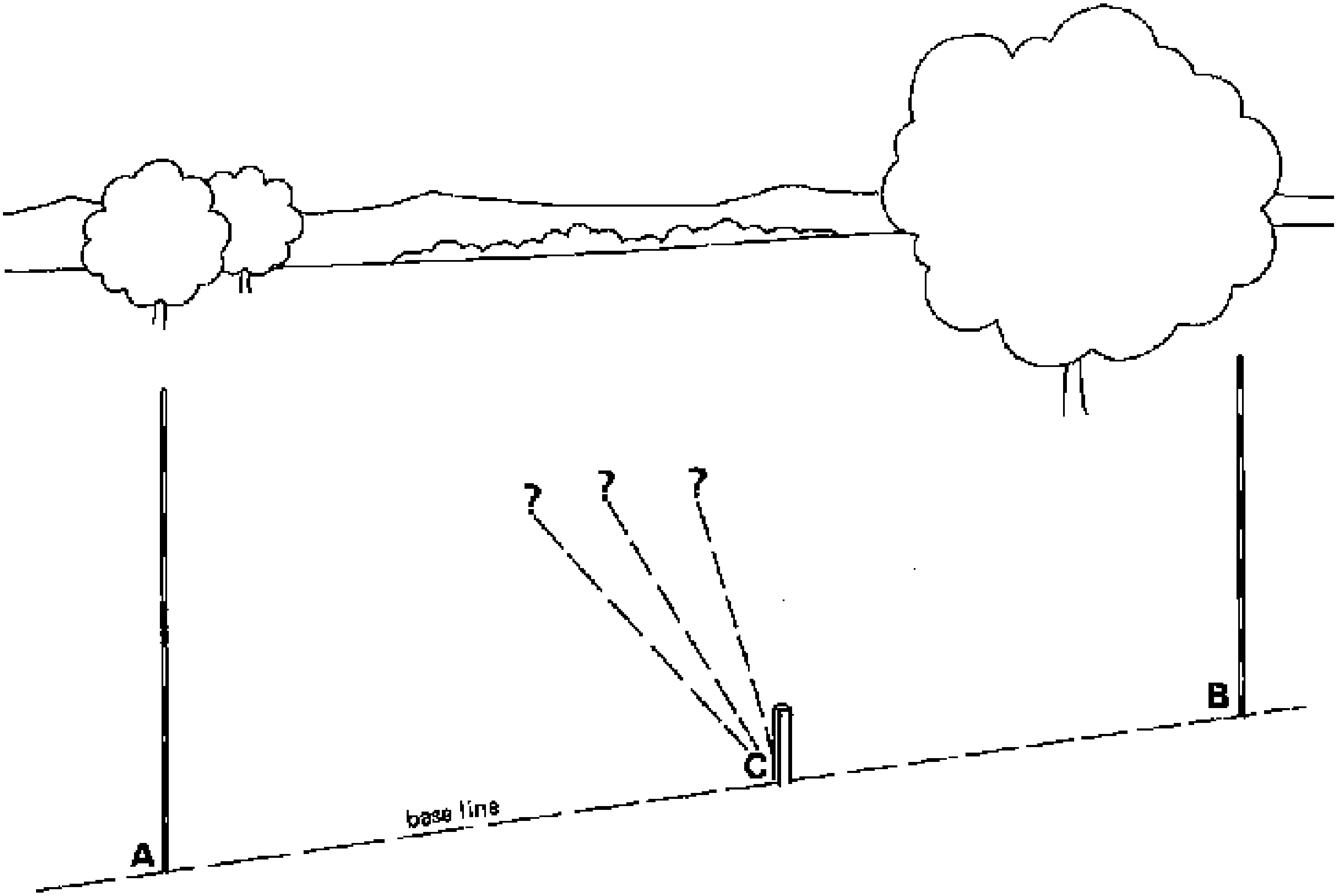
A
D
C
B
right
angle
base line
looking through the instrument
no right angle
right angle
D
A
D
A

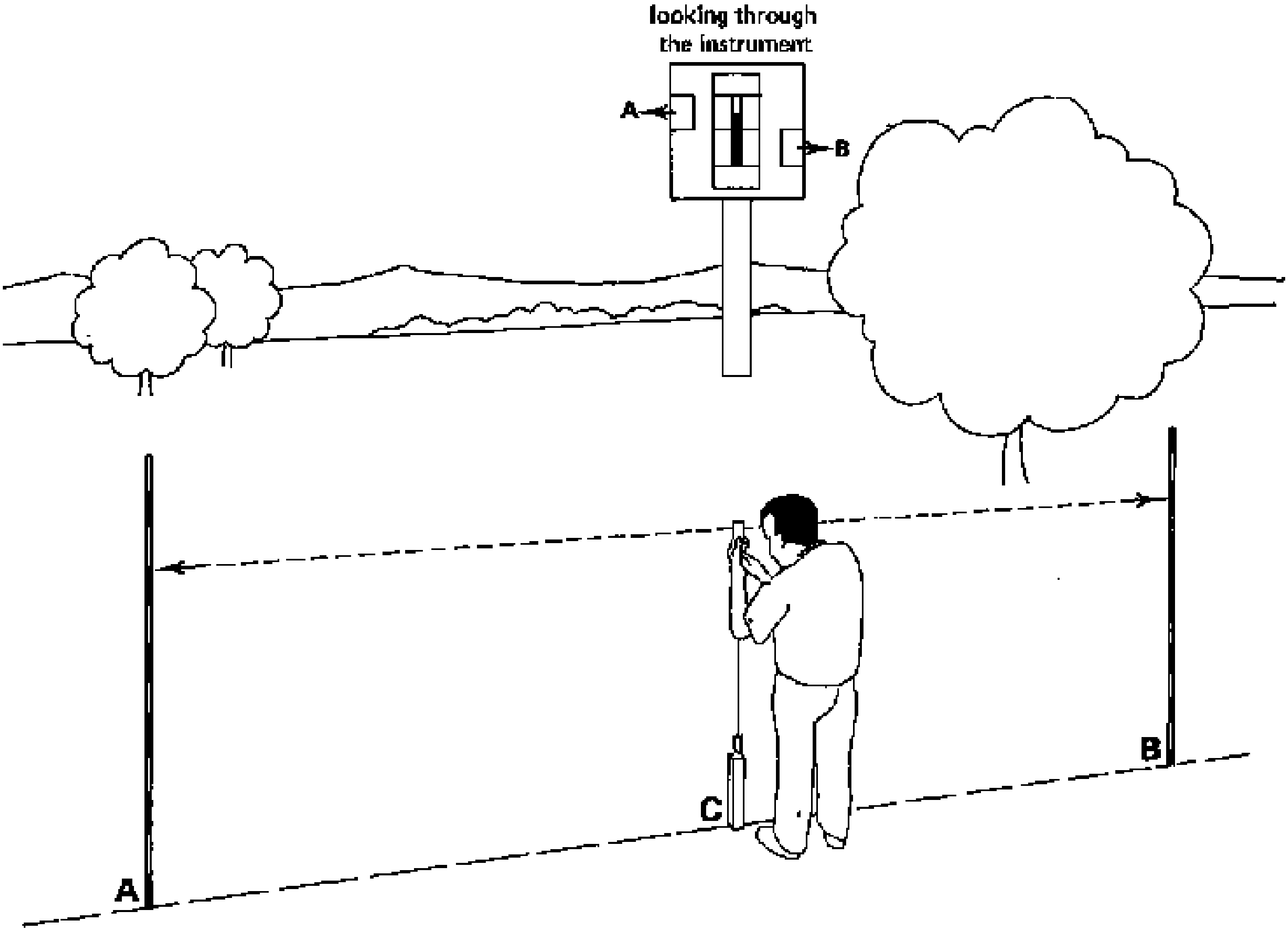

C
B
base line
A

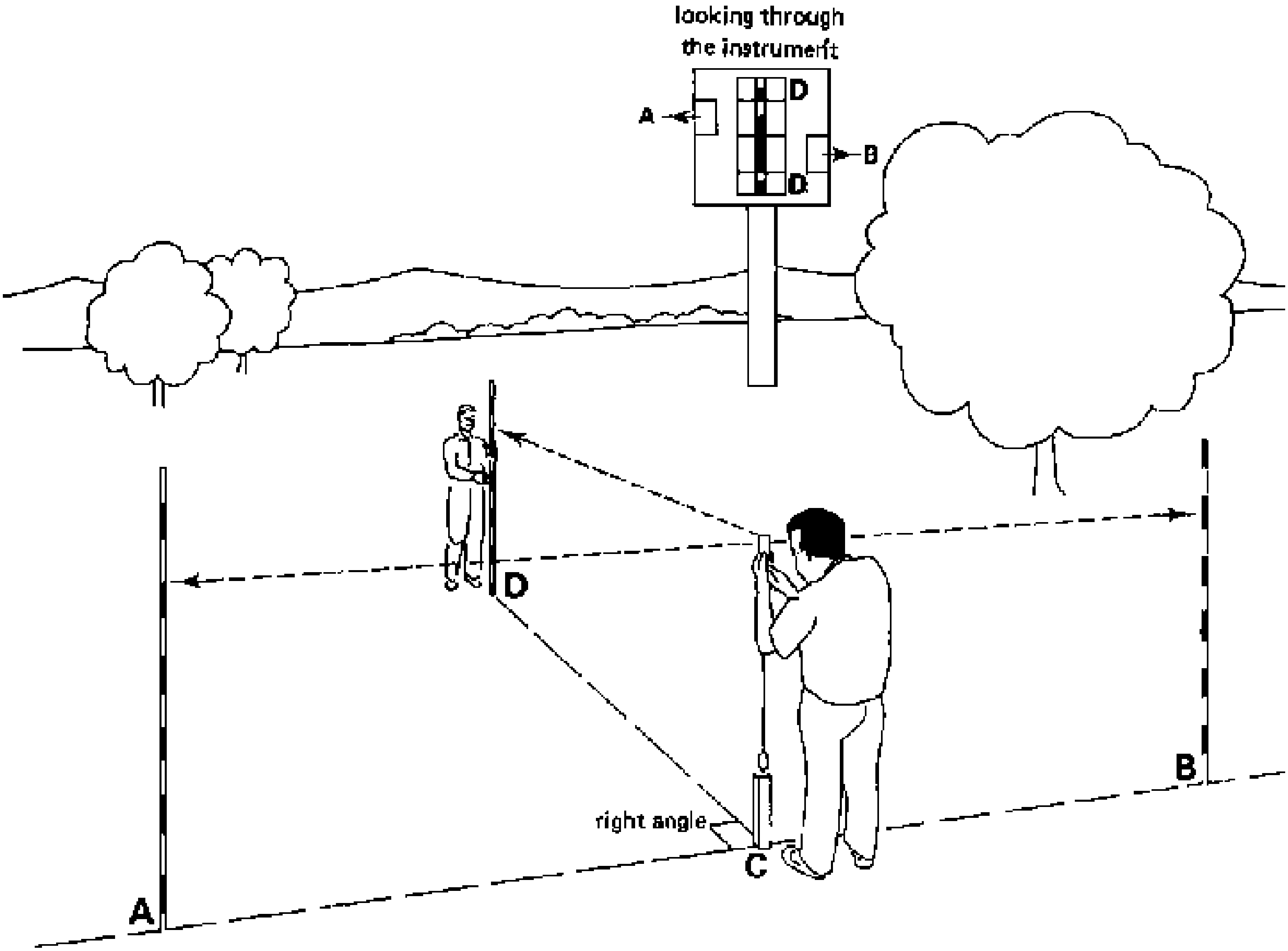

C
B
A
right angle
looking through
the instrument
A

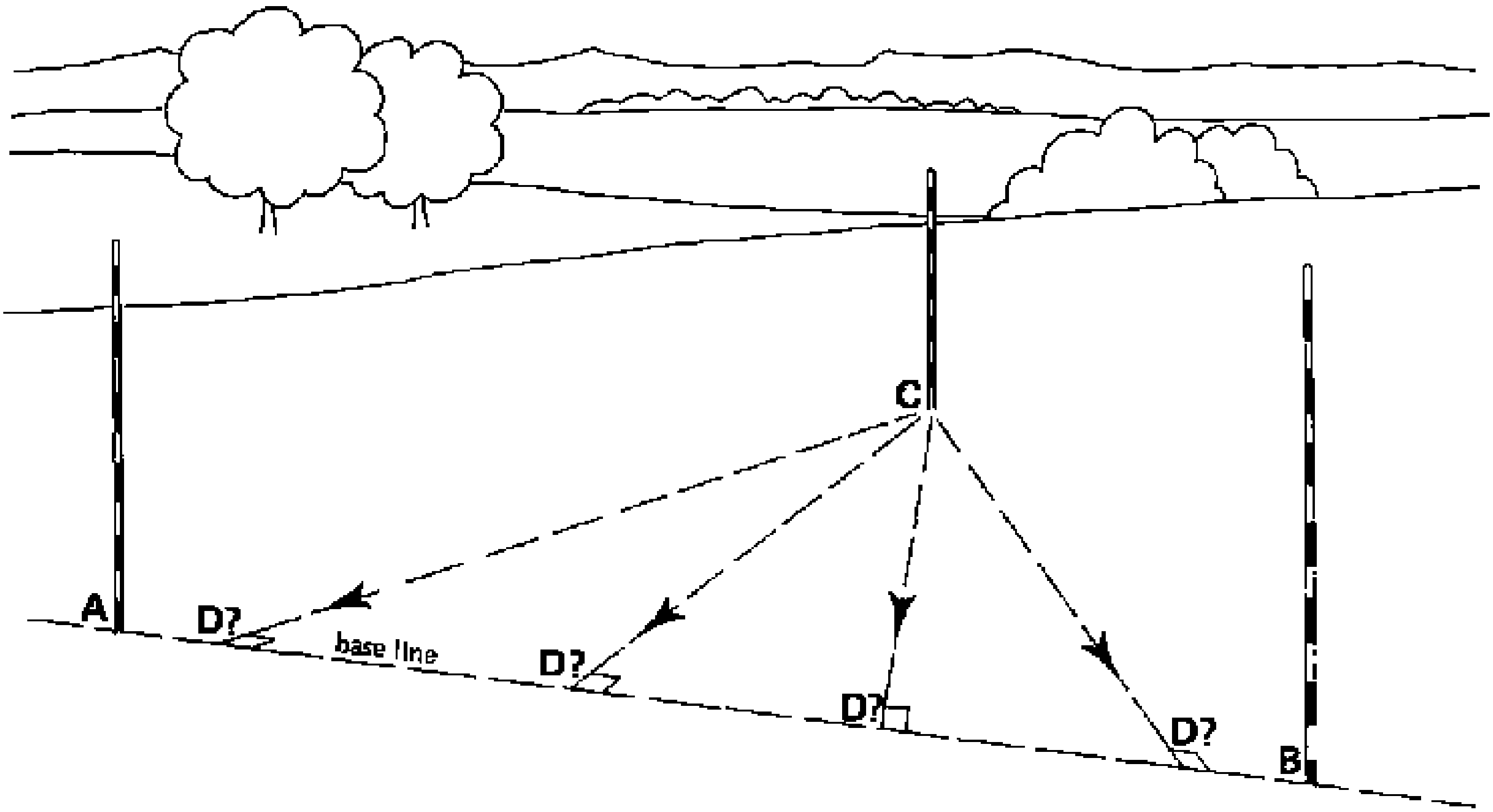

C
B
right angle
D
A
looking through the instrument
no right angle
right angle
C
A
C
A

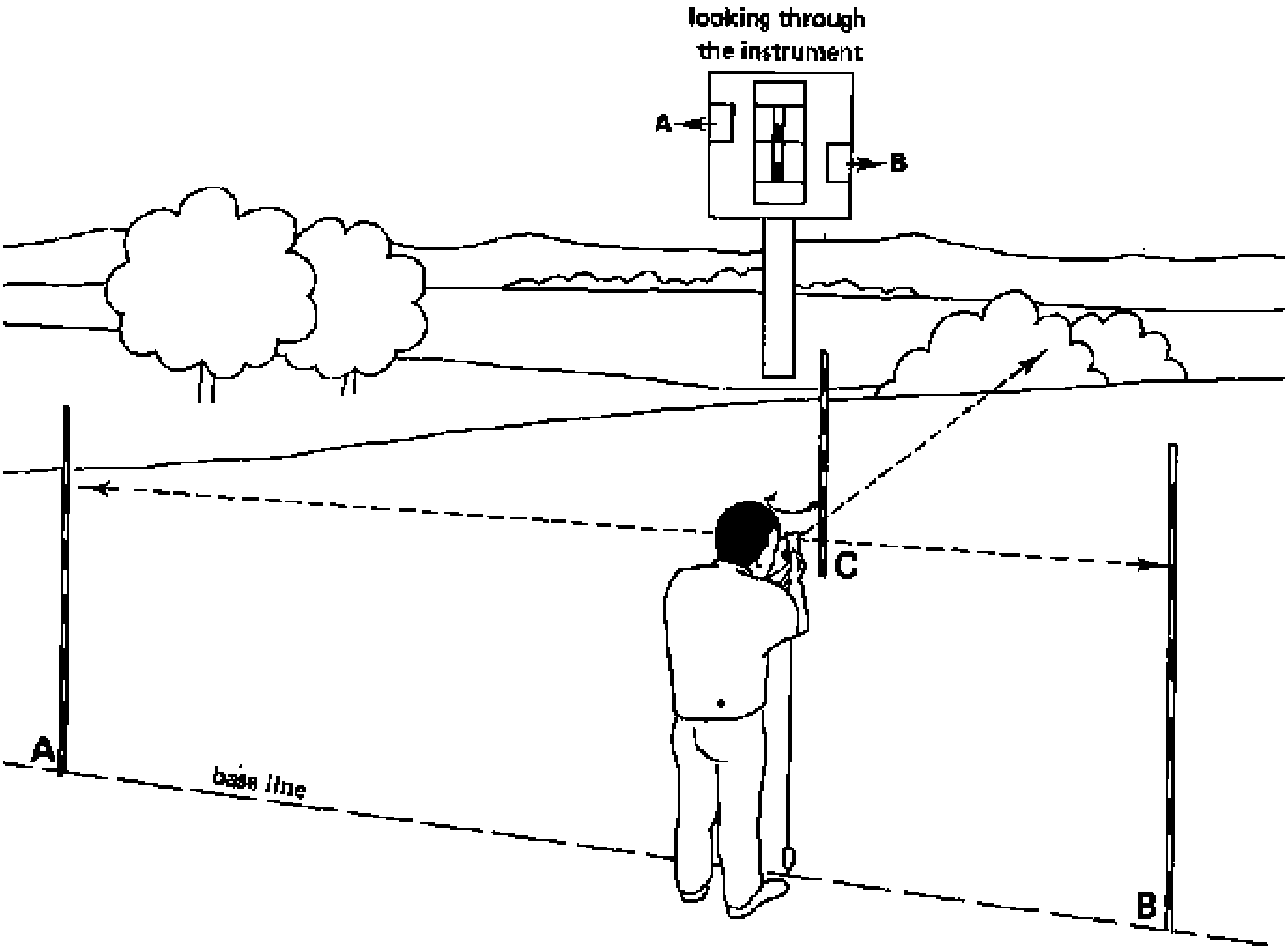

C
B
right angle D
A

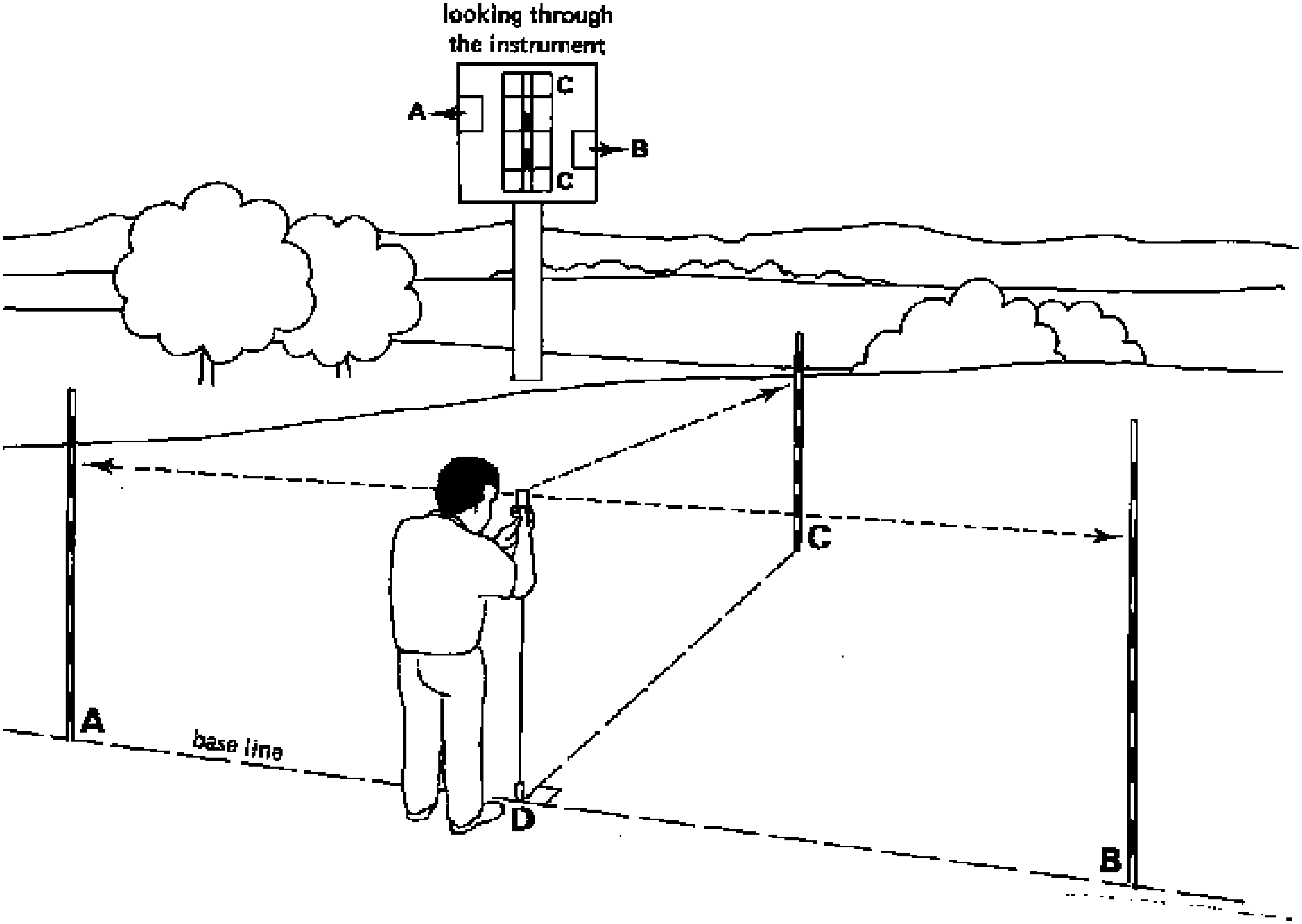

?
?
?
B
C
base line
A


looking through
the instrument
A
B
A
B
C

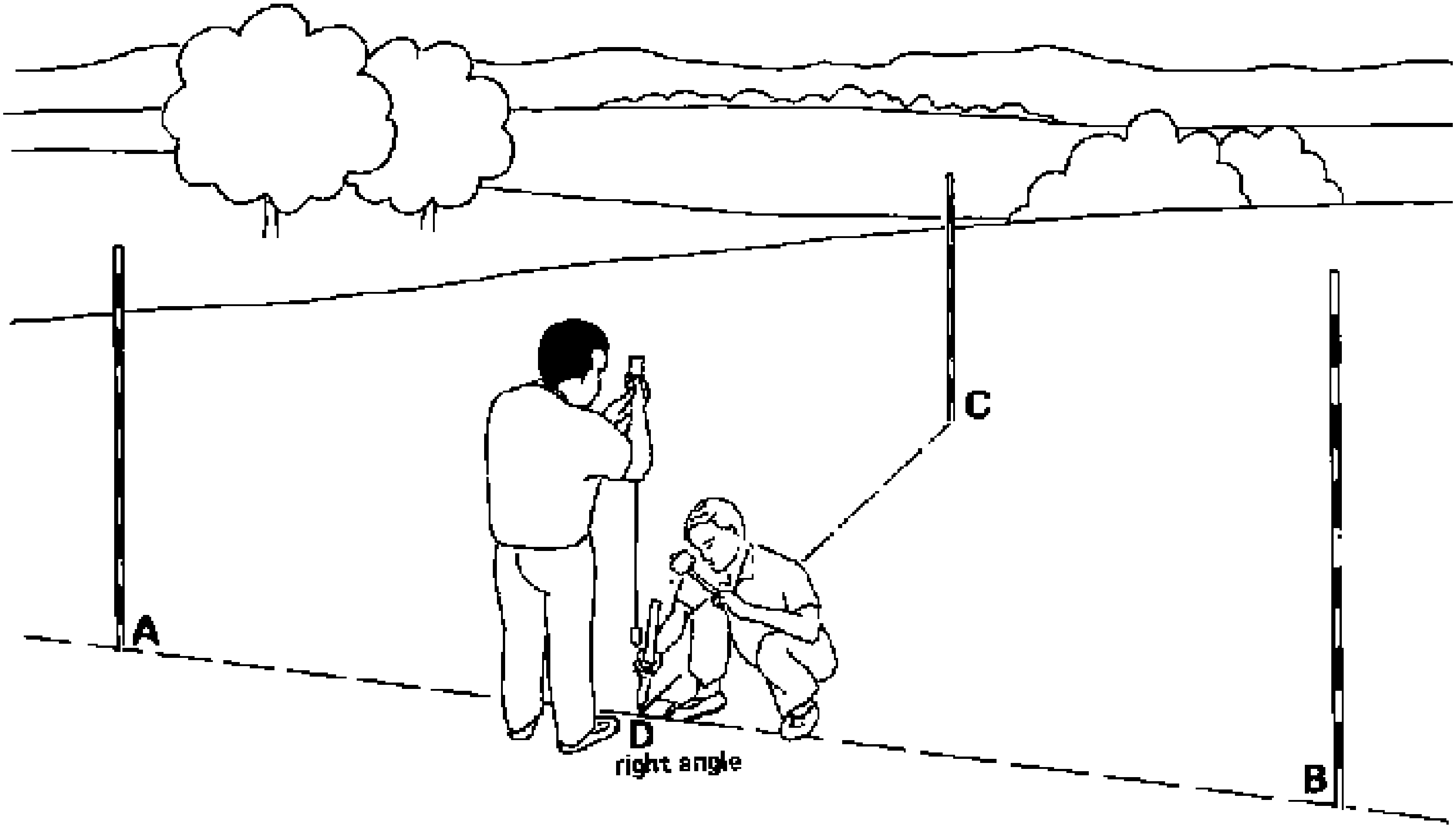

looking through
the instrument
D
A
B
D
D
right angle
C
A
B

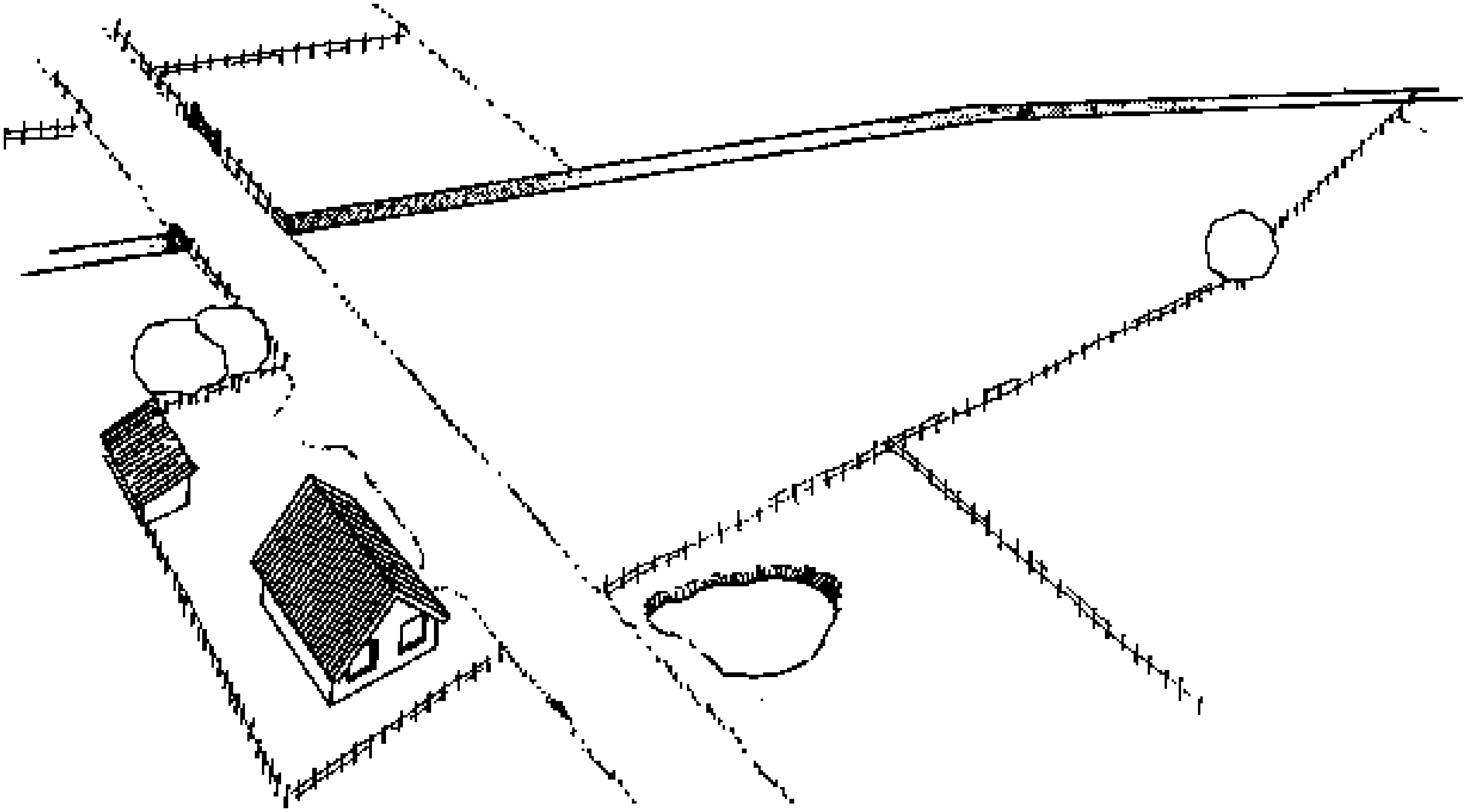

C
A
D?
base line
D?
D?
D?
B

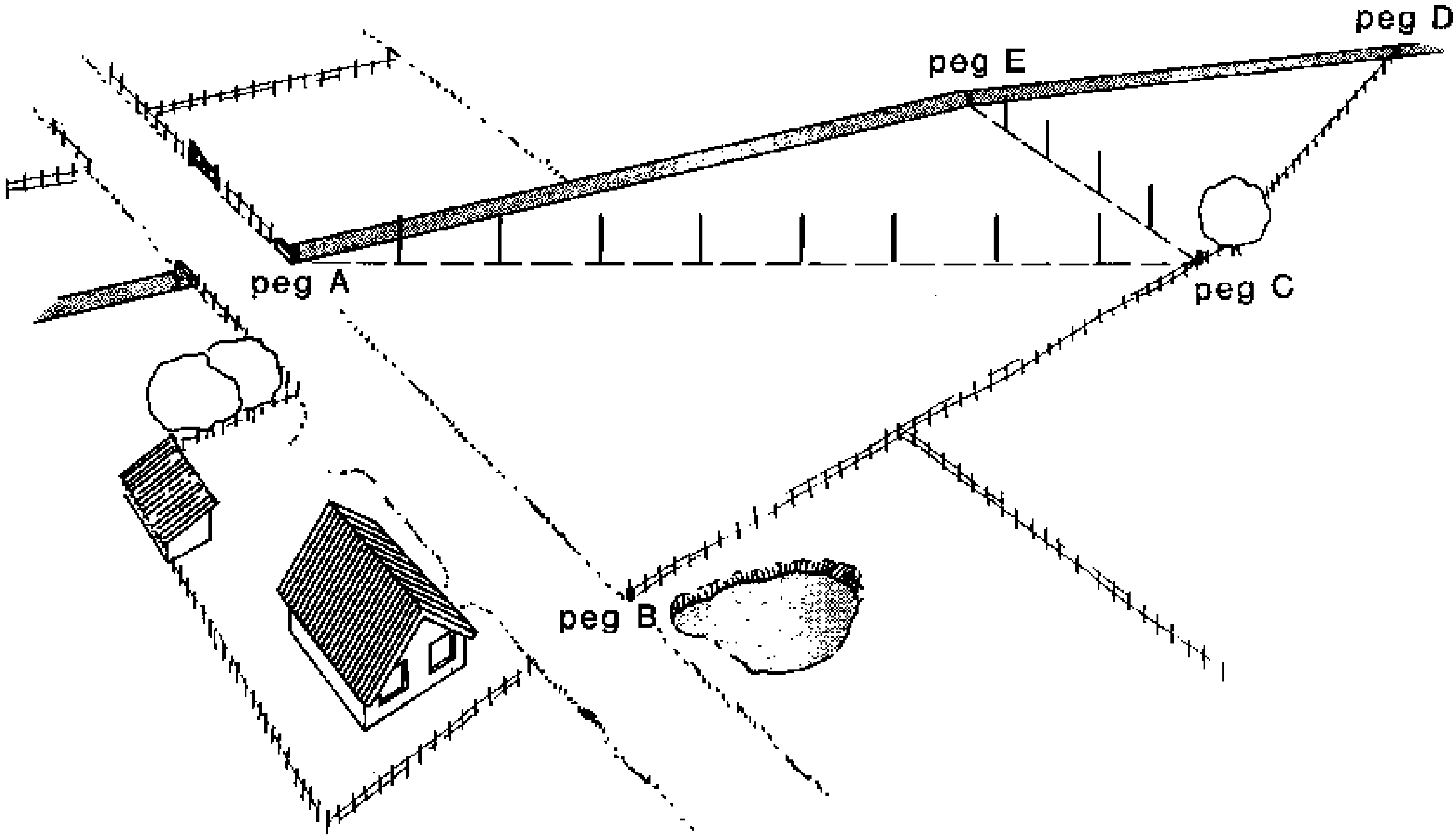

looking through
the instrument
A
B
C
A
base line
B

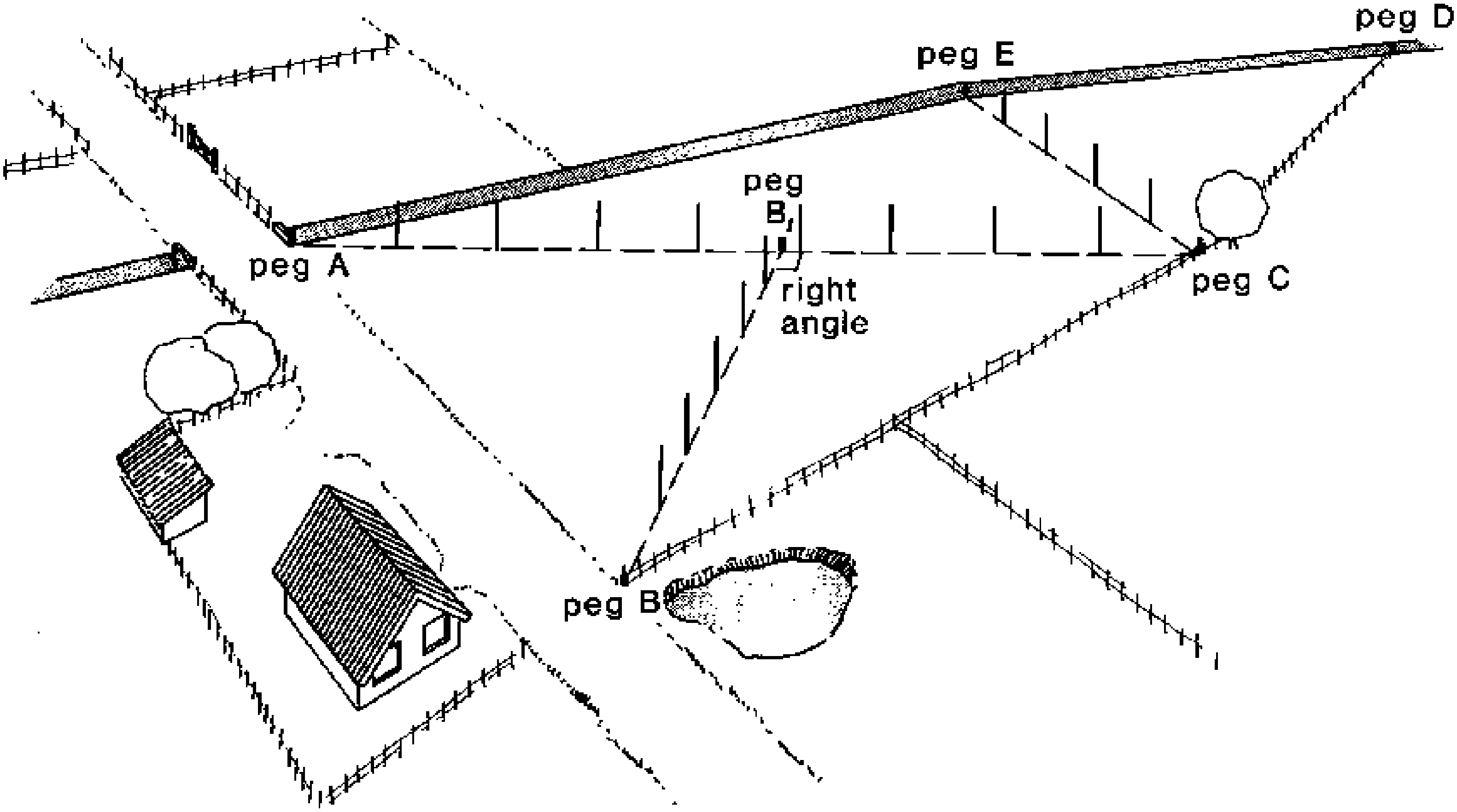


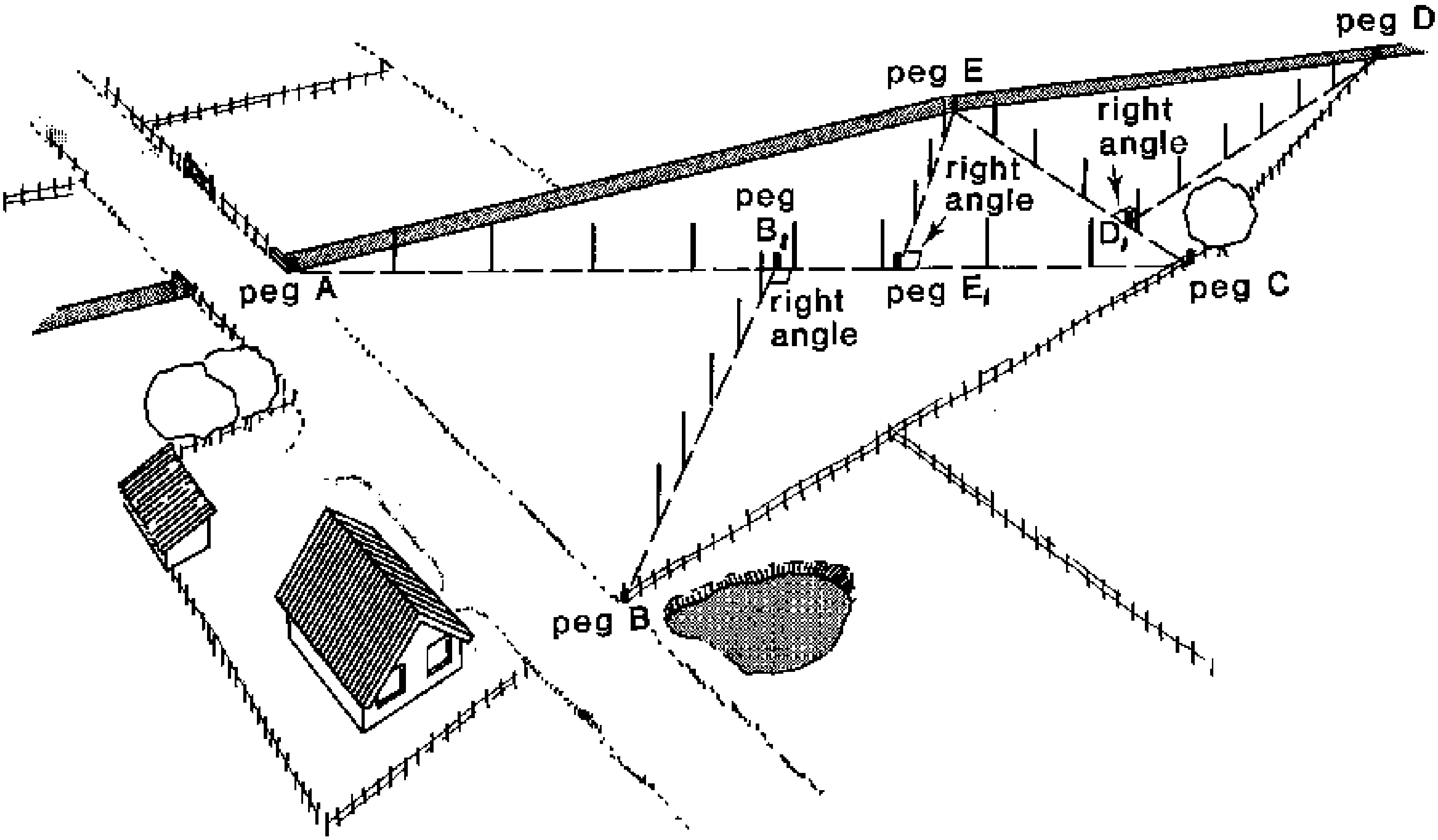
looking through
the instrument
A
B
C
C
A
C
D
B
base line

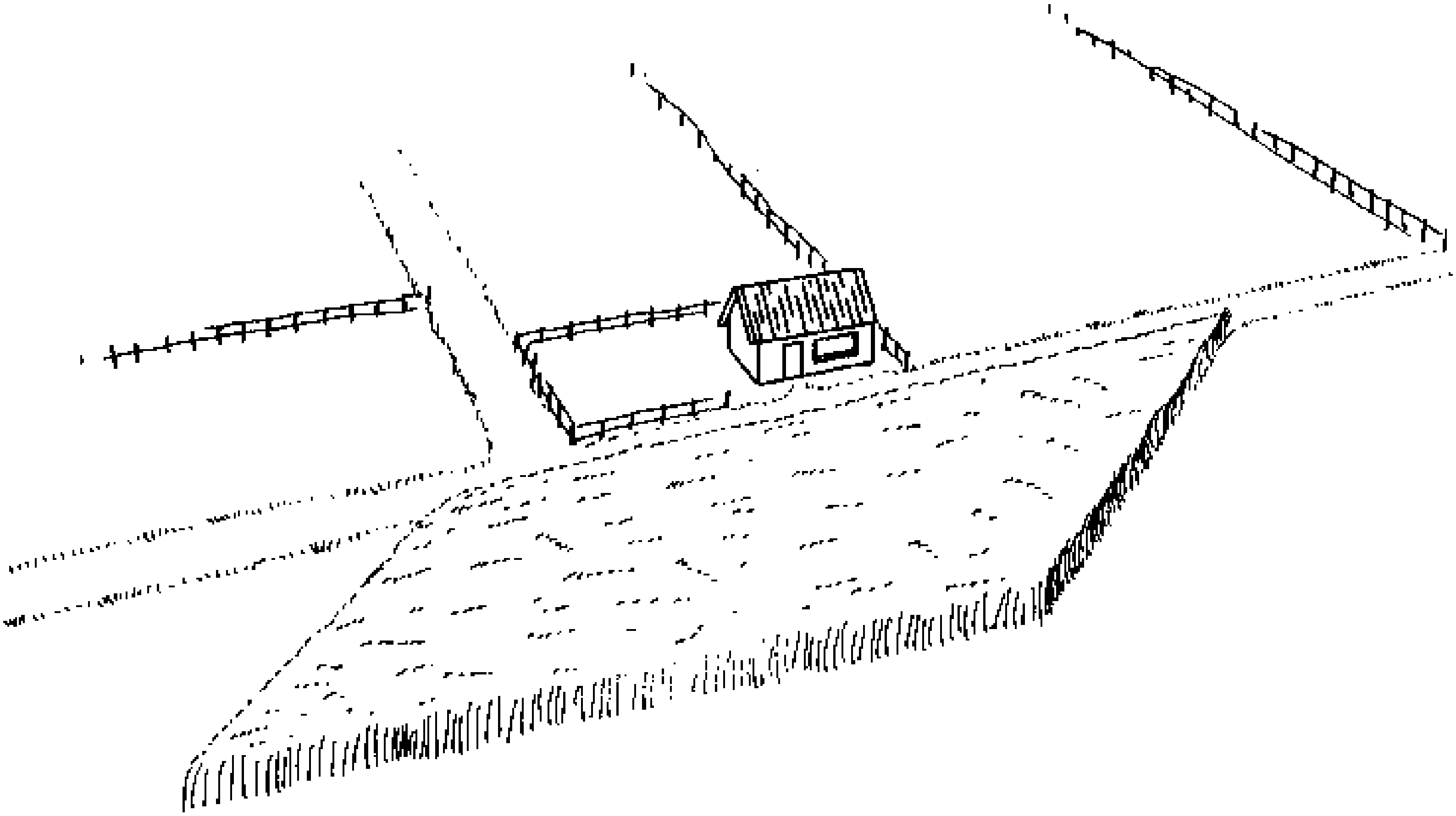

C
A
D
right angle
B

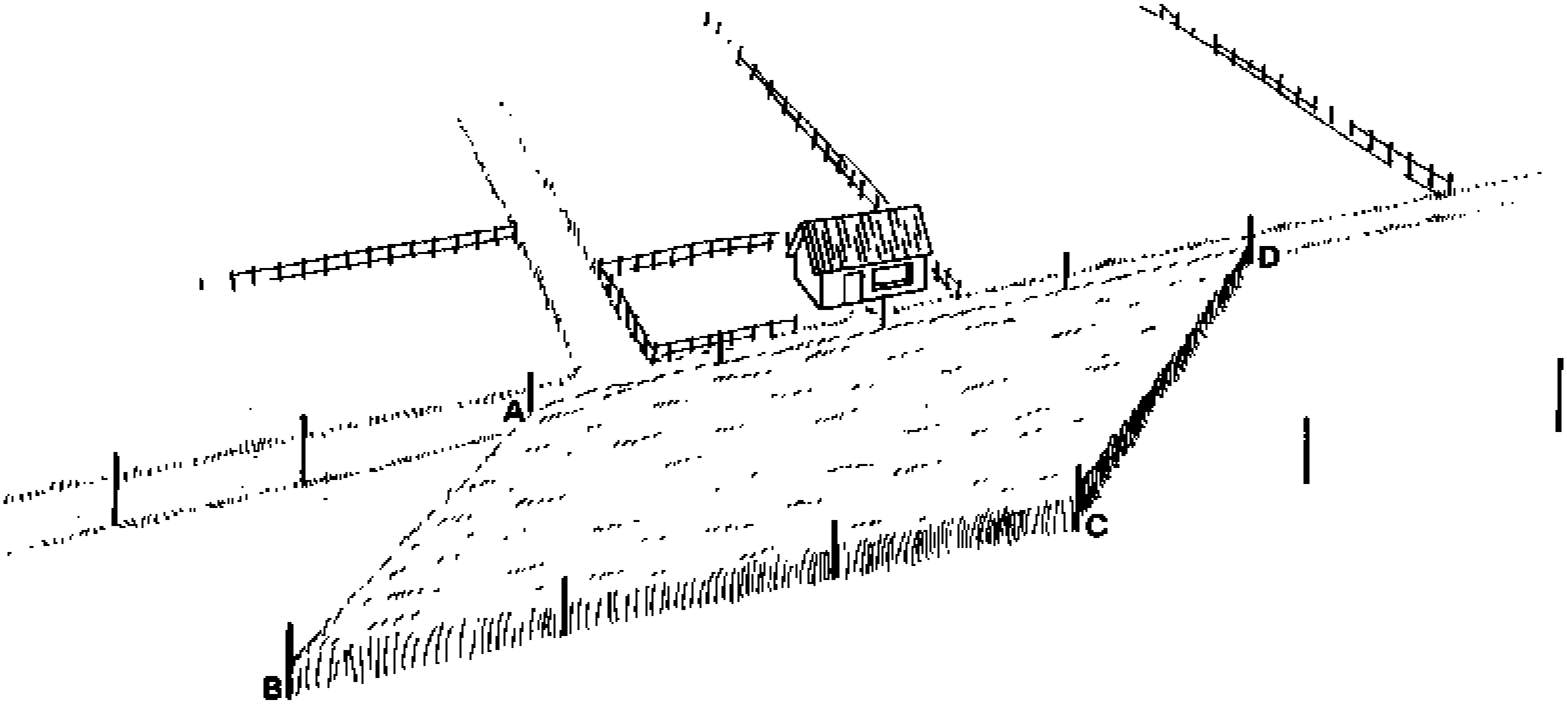


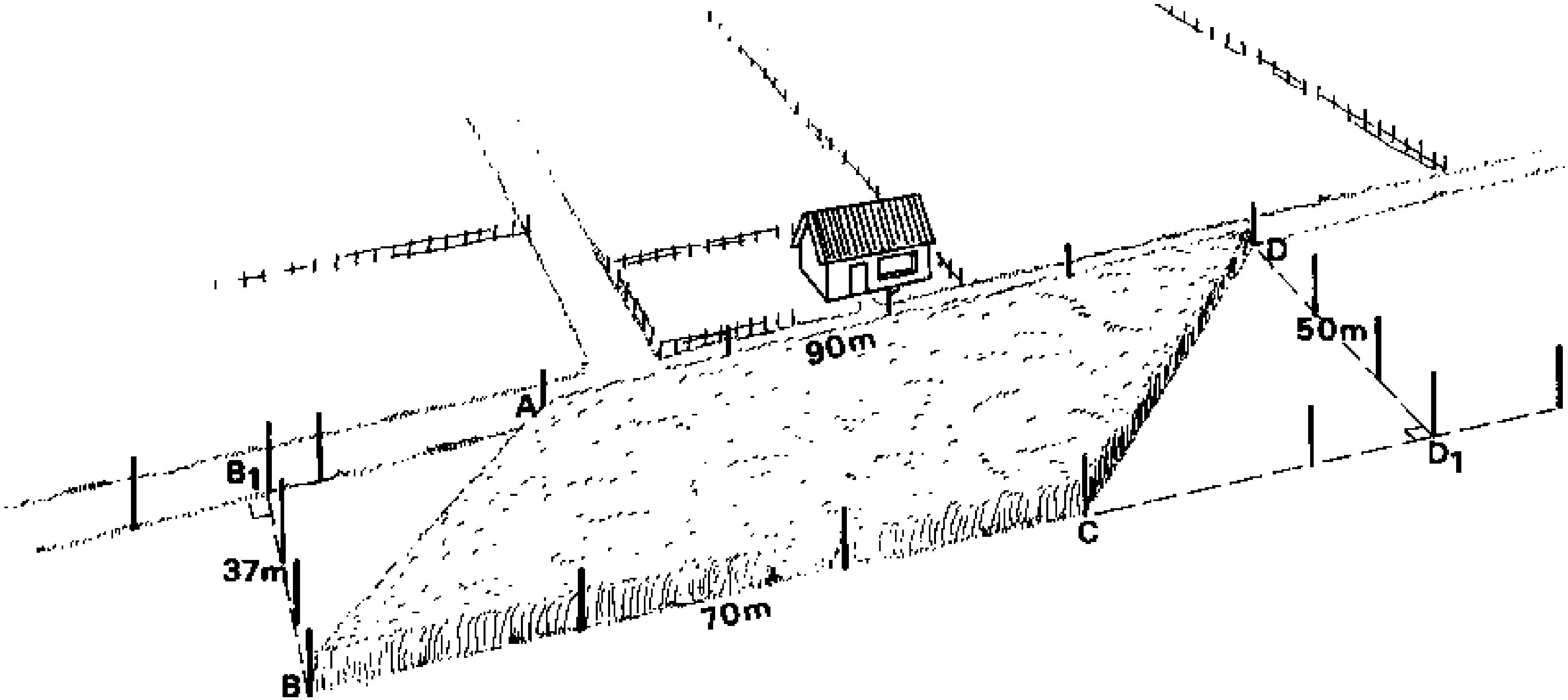

peg D
peg E
peg A
peg C
peg B


peg D
peg E
peg B₁
peg A
right angle
peg C
peg B

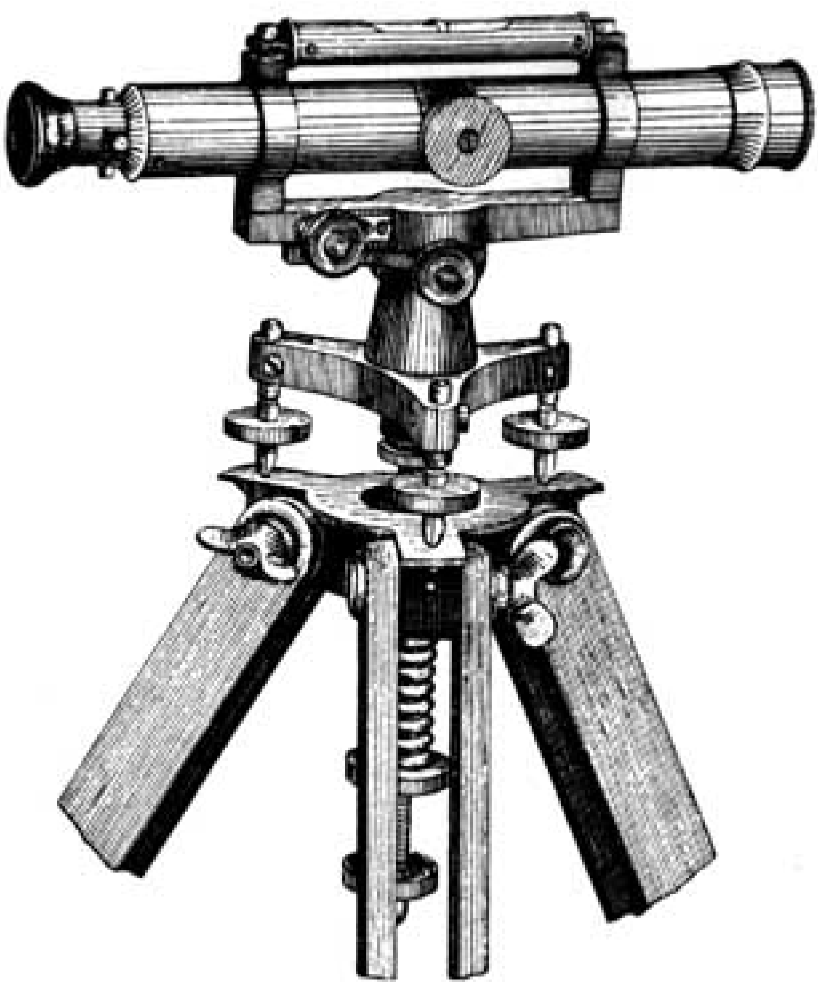

peg D
peg E
right angle
right angle
peg B1
right angle
peg A
peg E1
peg C
D1
right angle
peg B

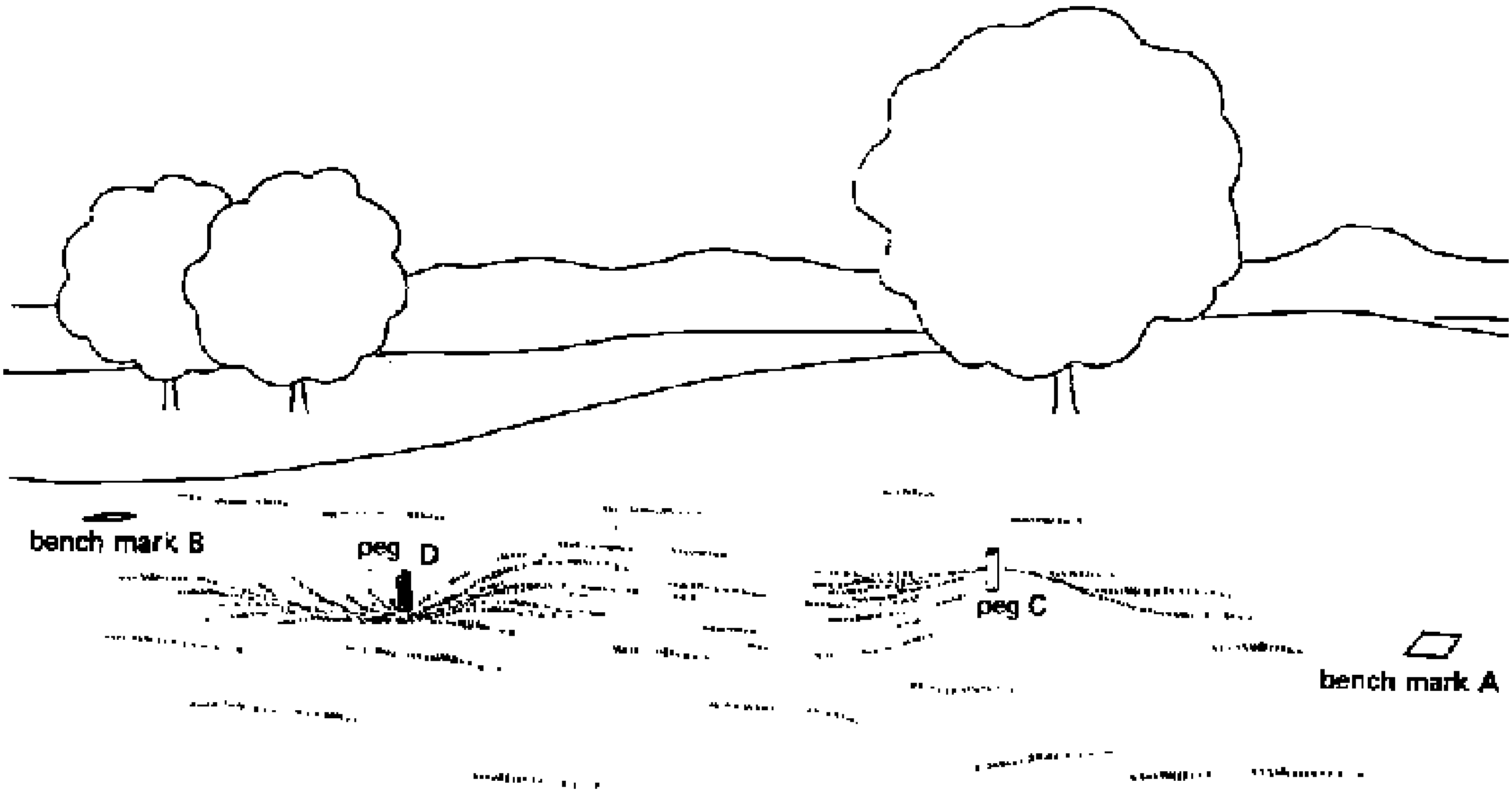


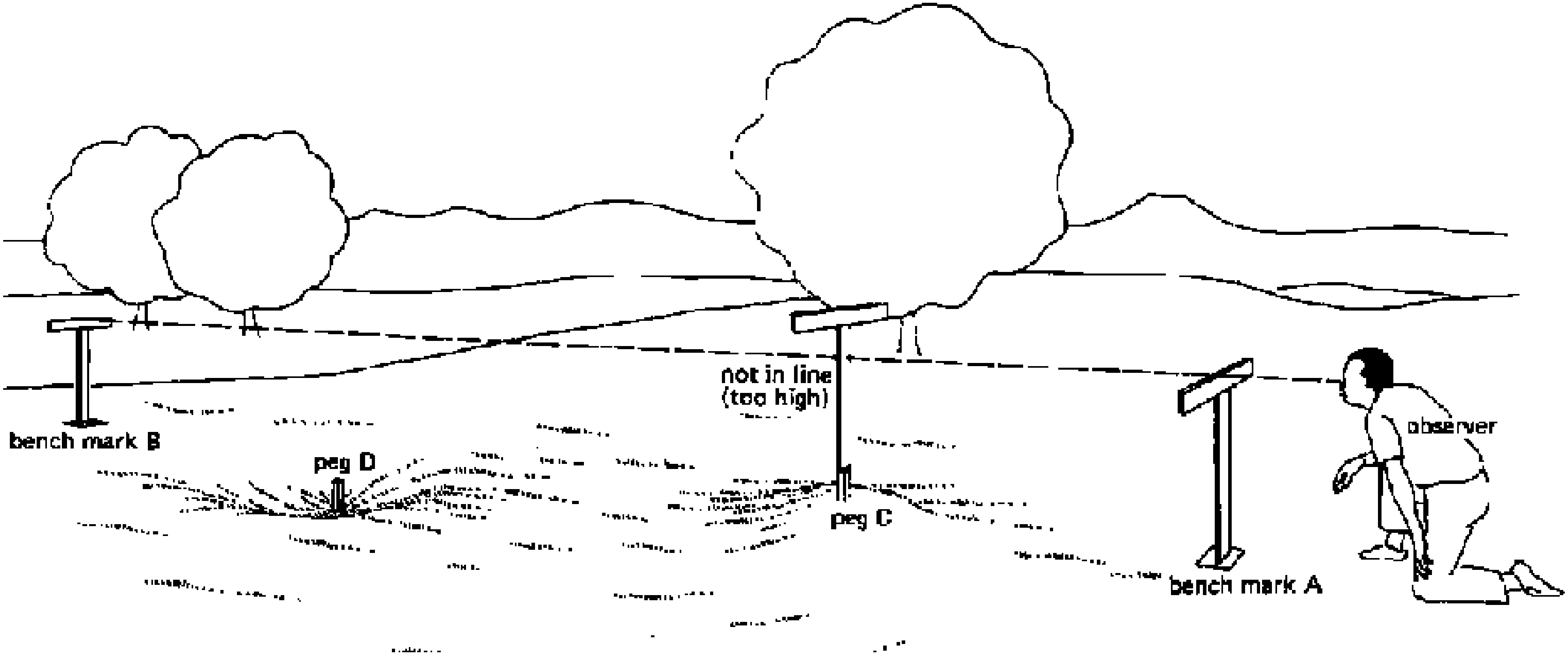

A
B
C
D

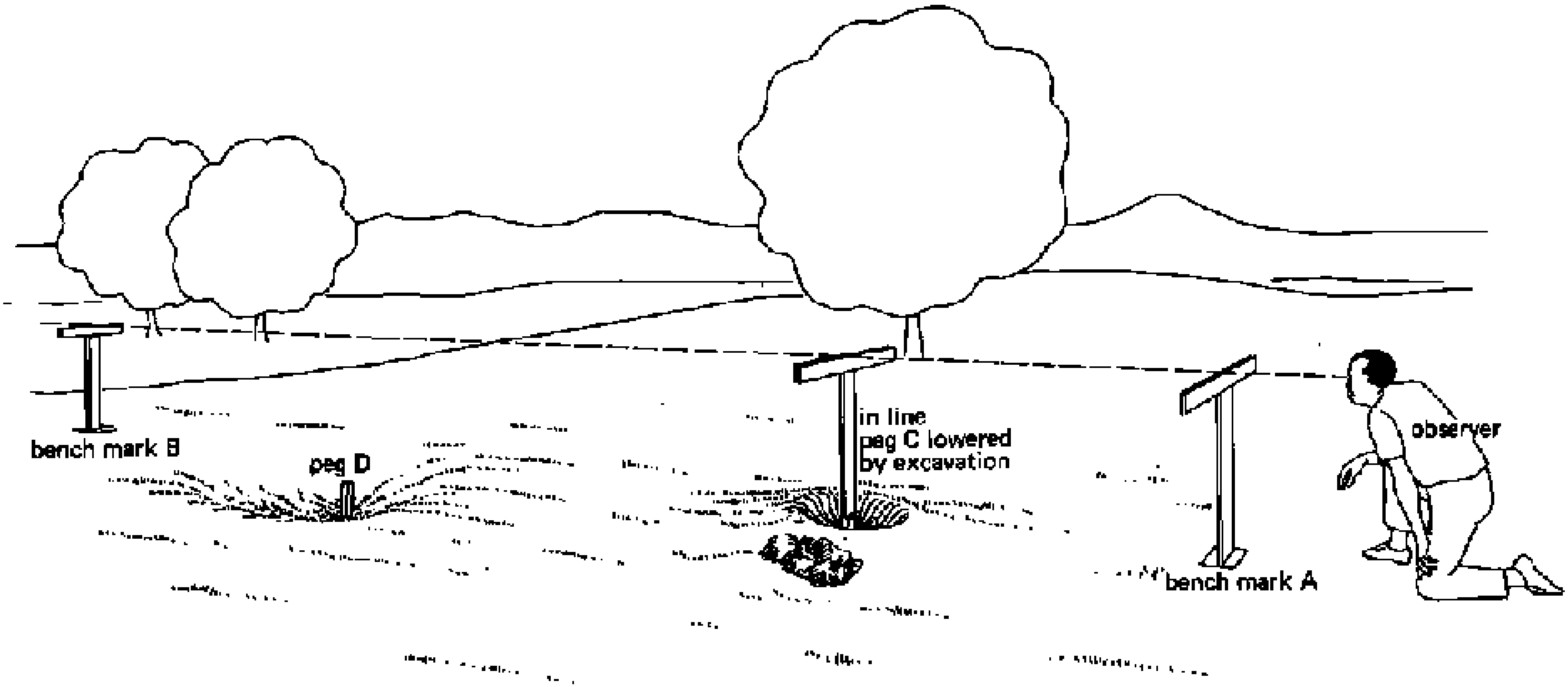


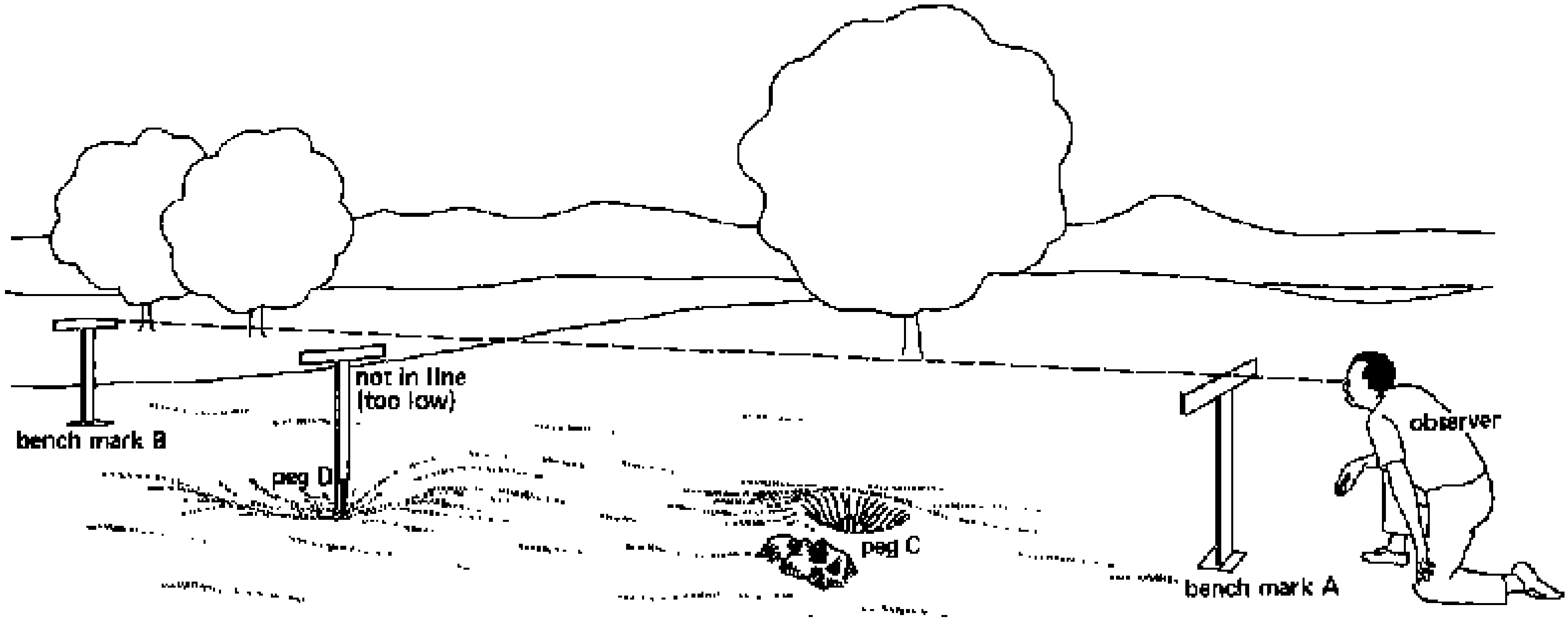
90m
D
50m
A
B1
D1
C
37m
70m
B

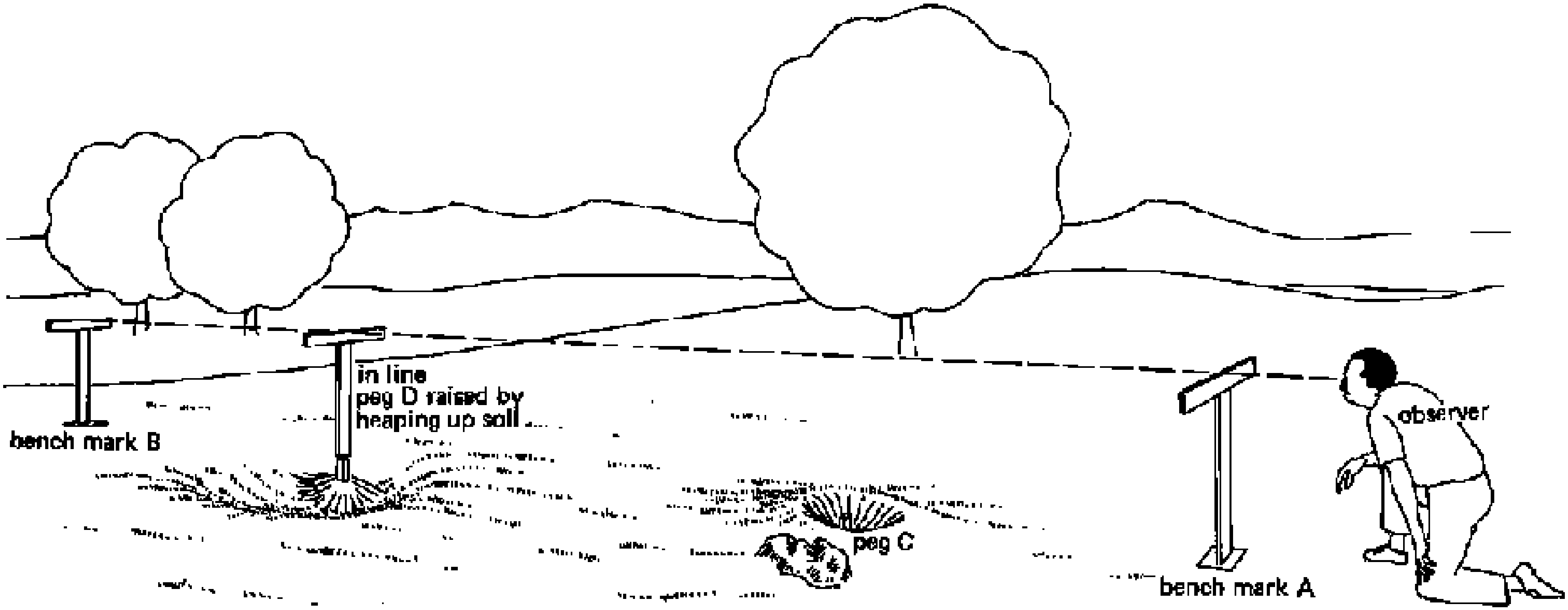


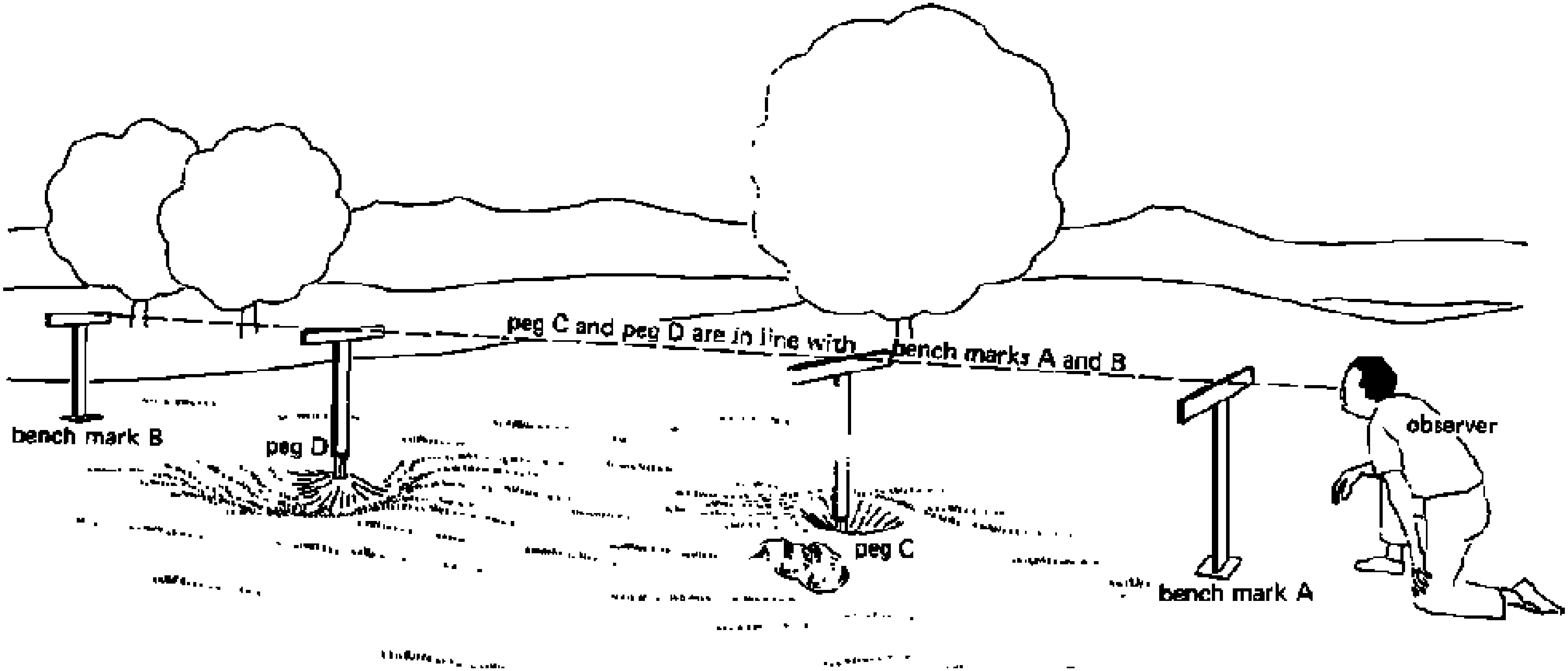

bench mark B
peg D
peg C
bench mark A

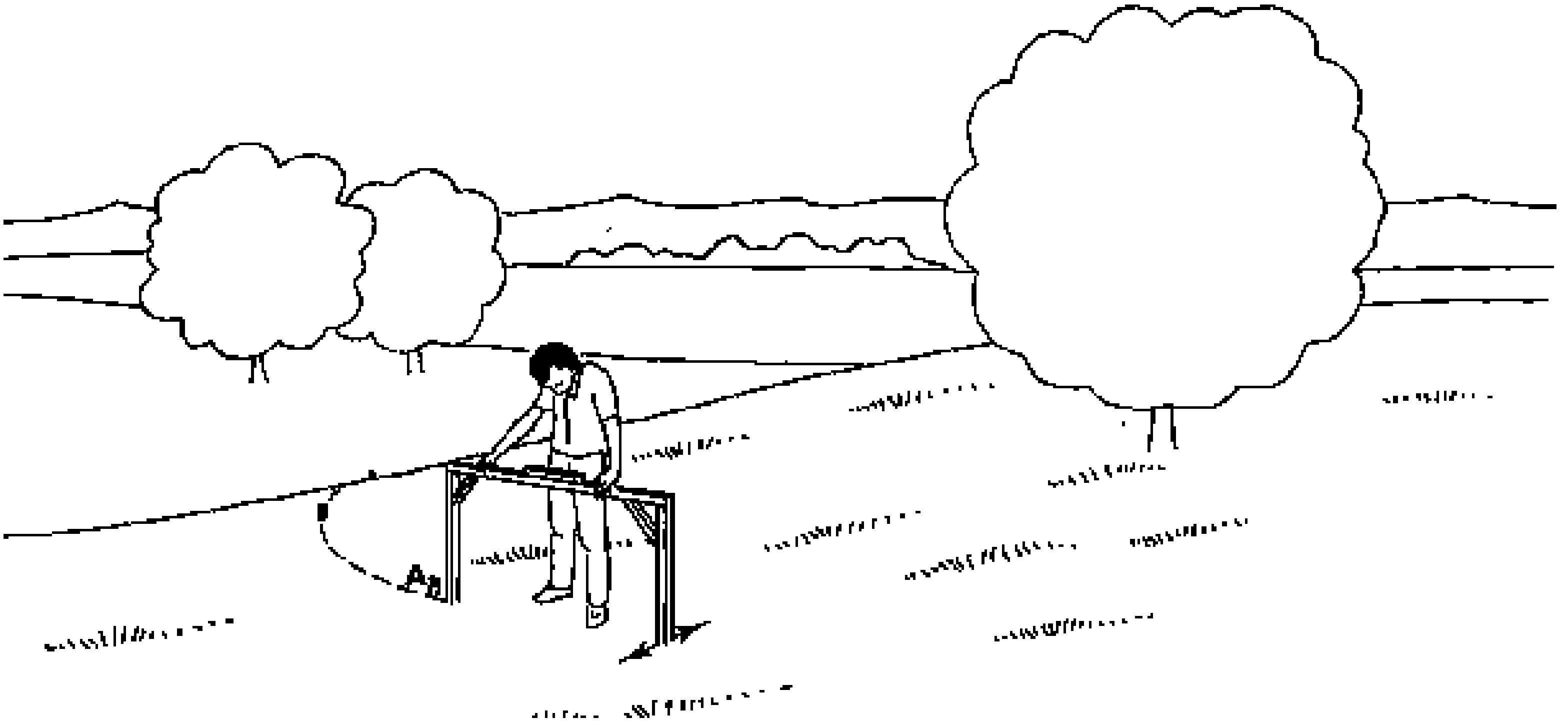

bench mark B
peg D
not in line
(too high)
peg C
bench mark A
observer

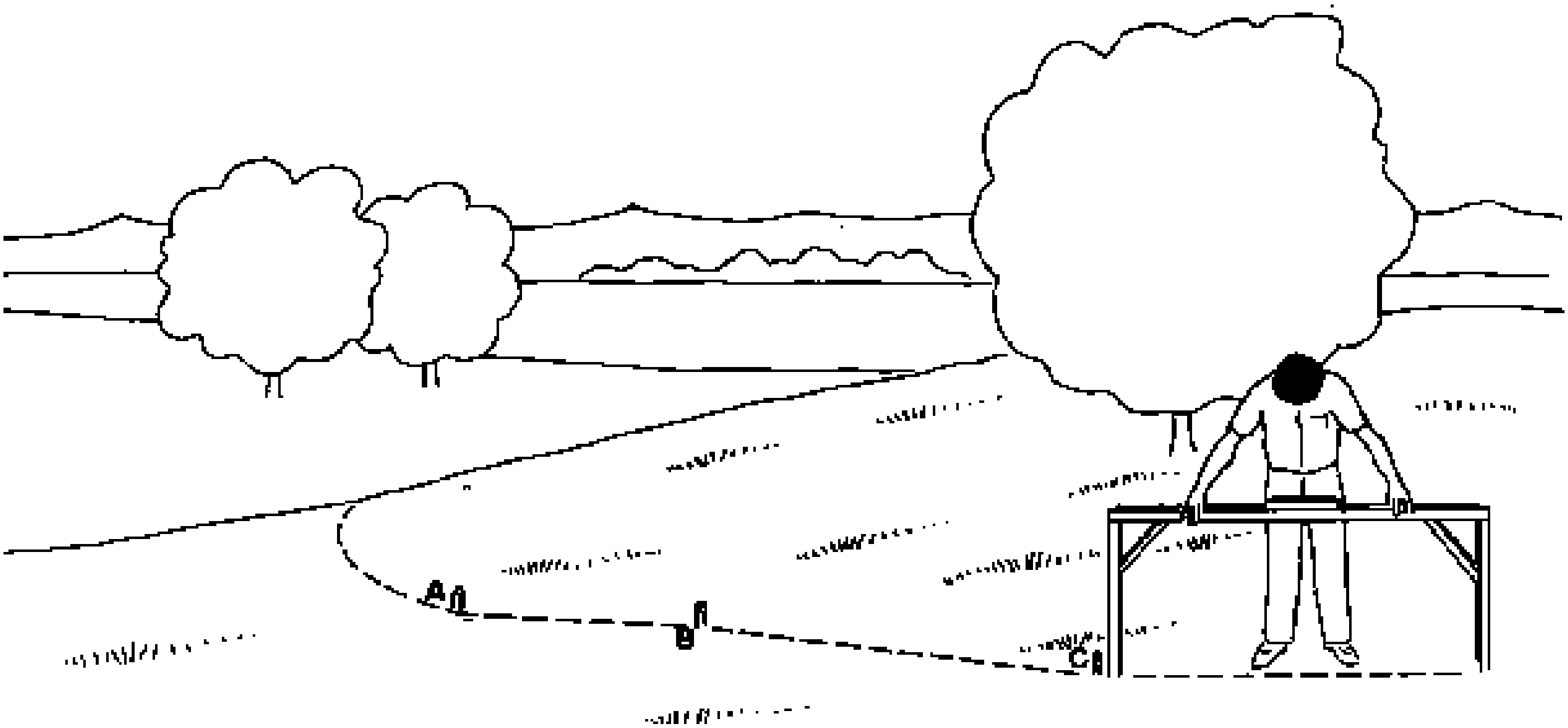

bench mark B
peg D
in line
peg C lowered
by excavation
observer
bench mark A

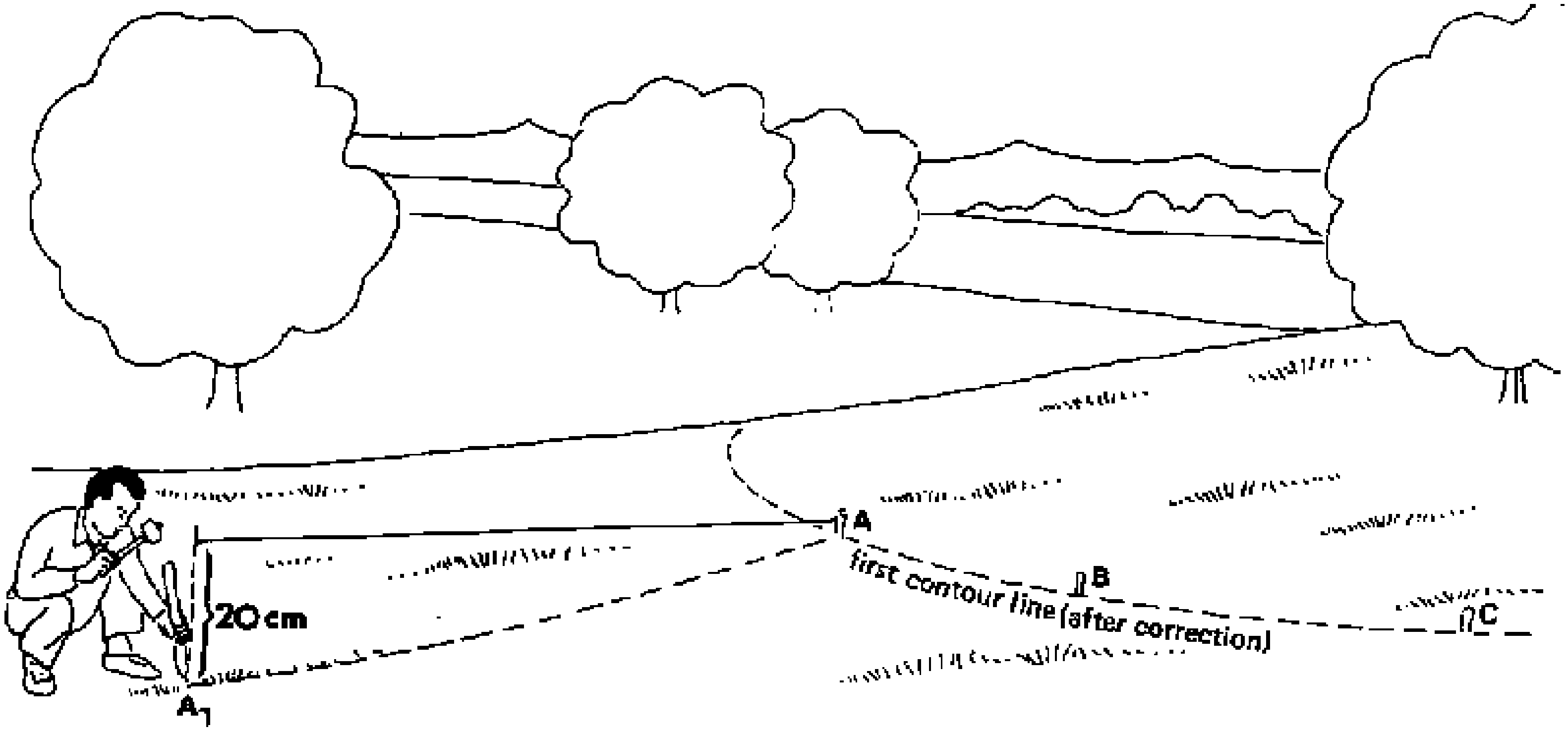

not in line
(too low)
bench mark B
peg D
peg C
observer
bench mark A

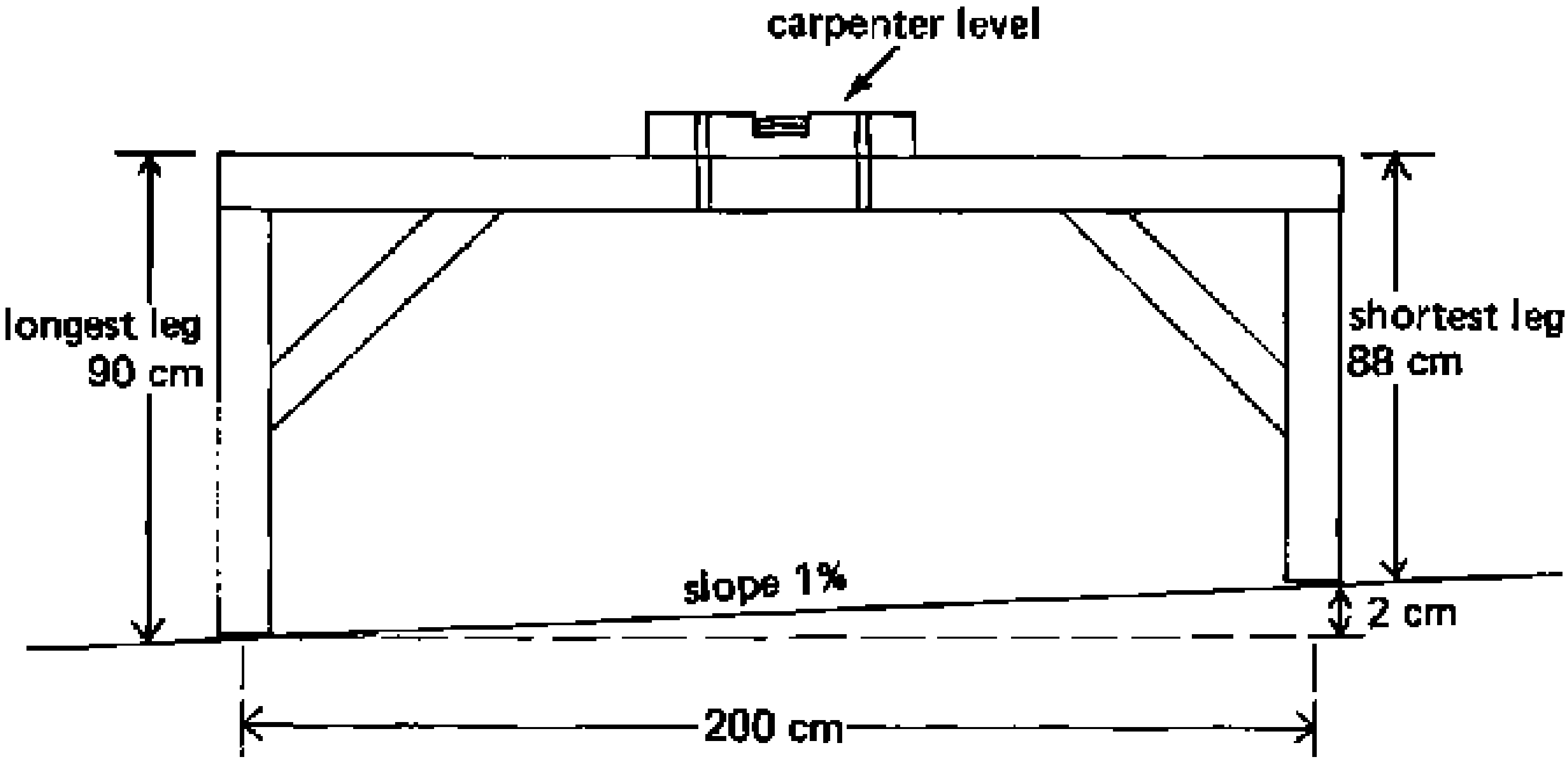

in line
peg D raised by
heaping up soil
bench mark B
peg C
bench mark A
observer

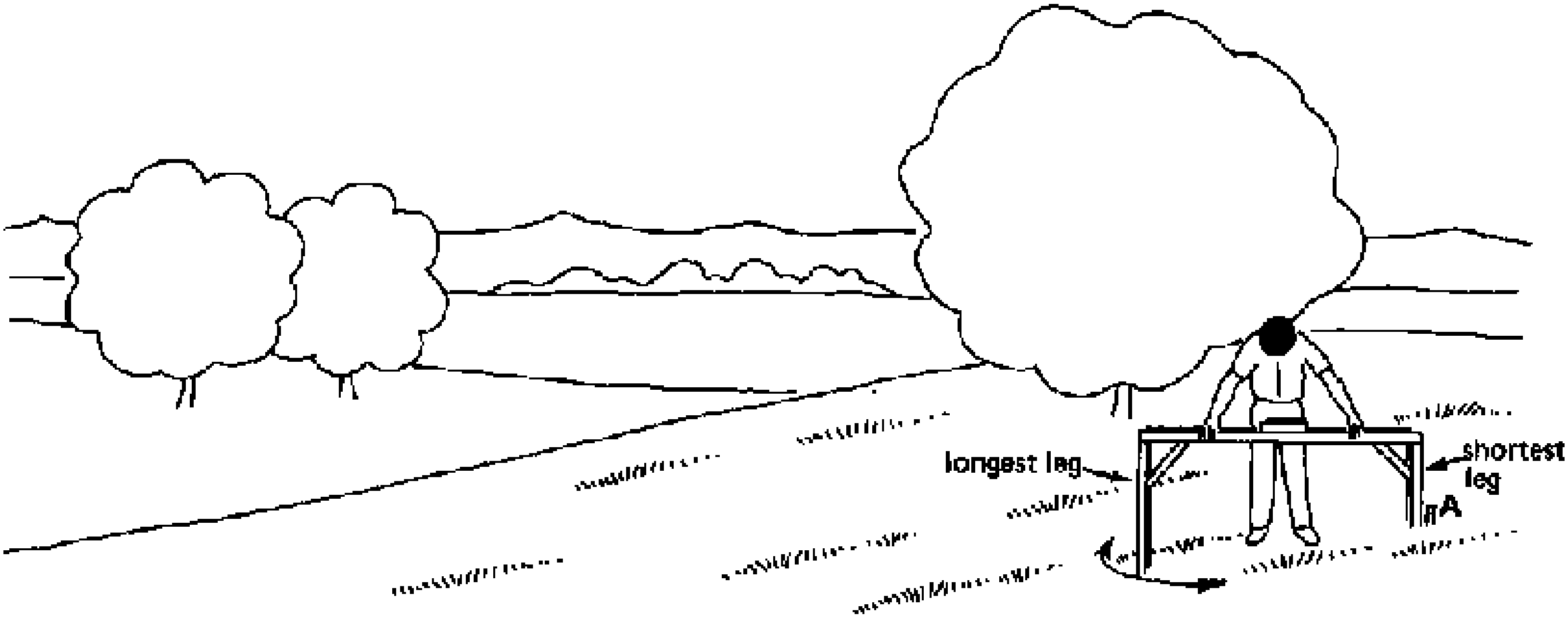

peg C and peg D are in line with bench marks A and B
bench mark B
peg D
peg C
bench mark A
observer

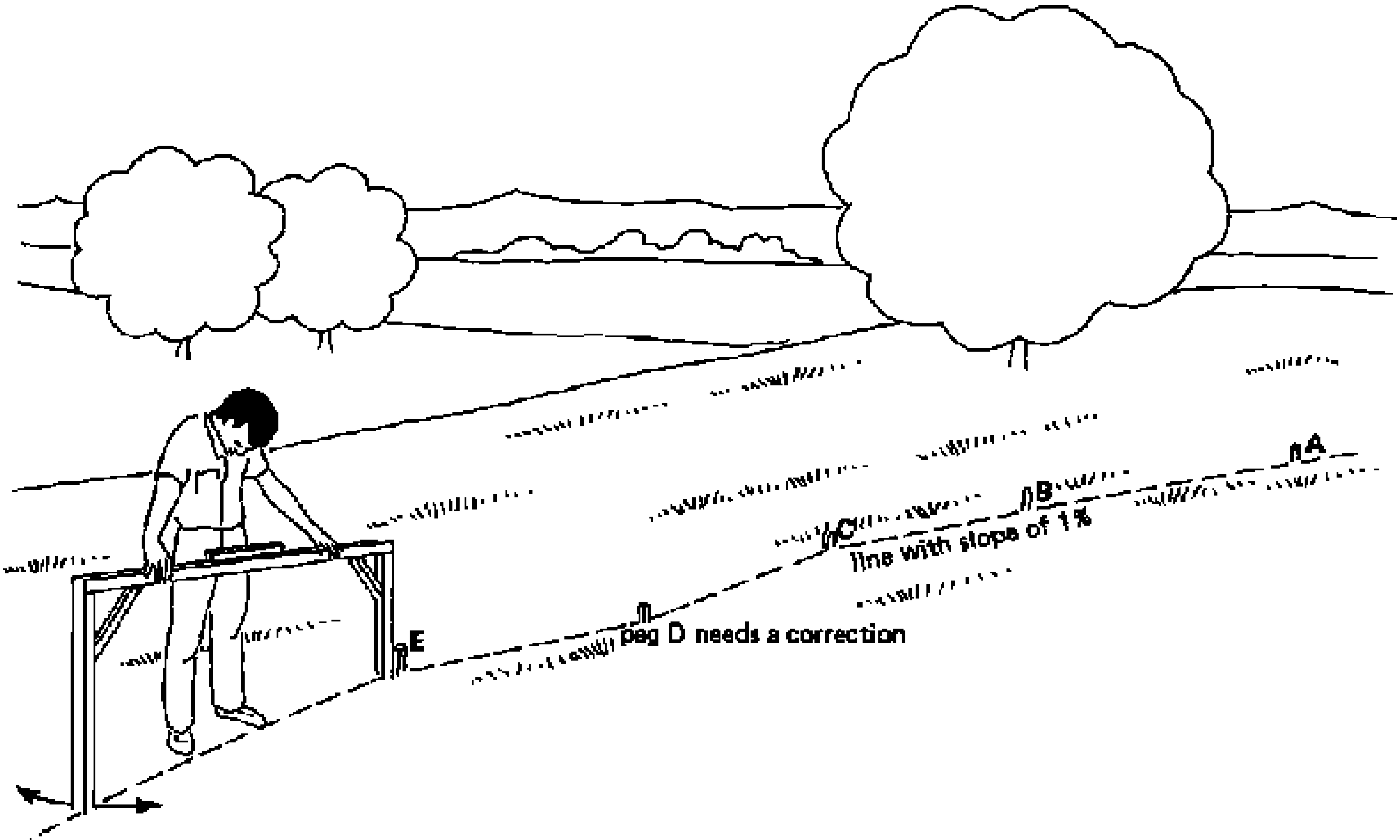


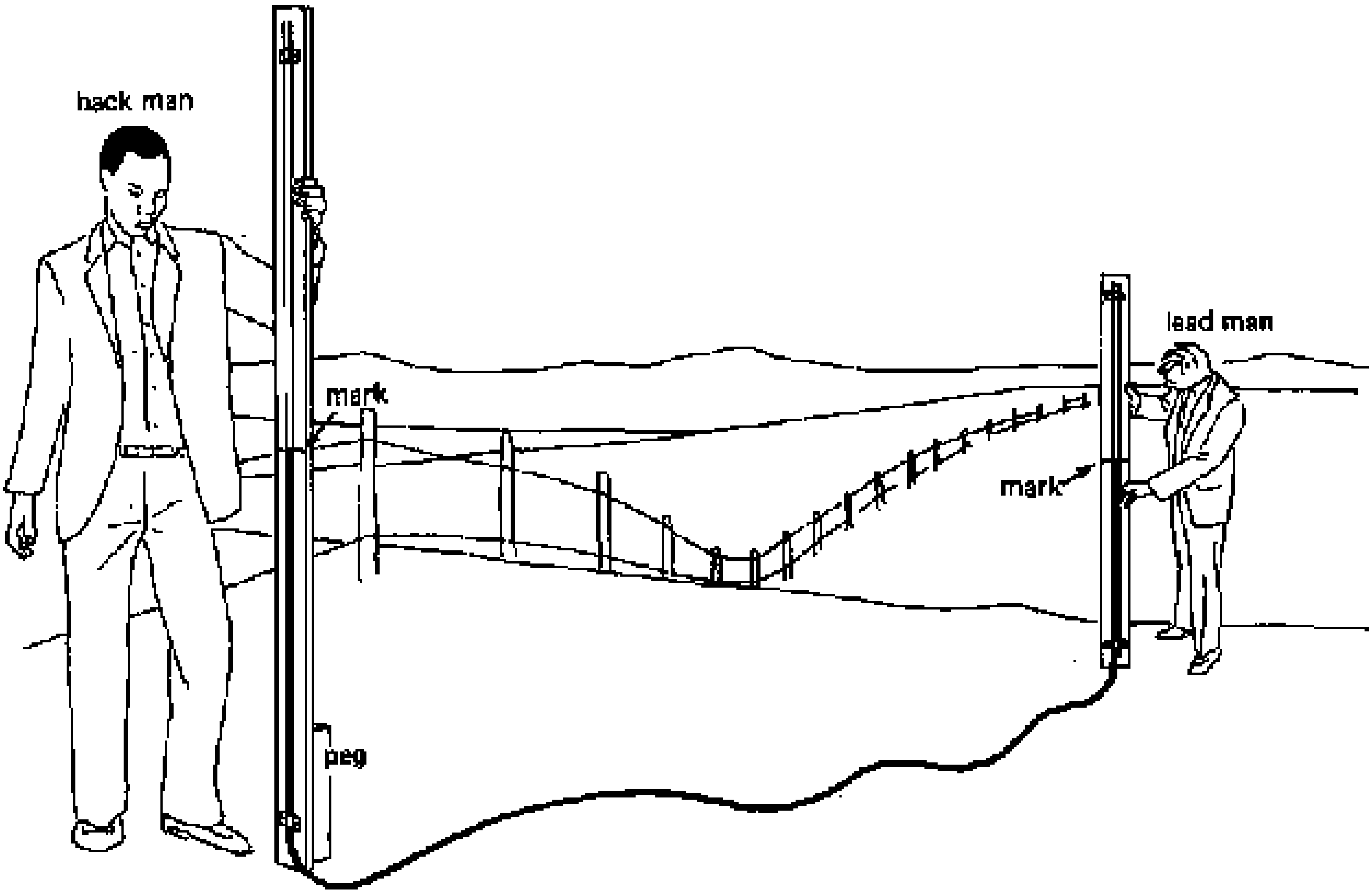

A
B
C

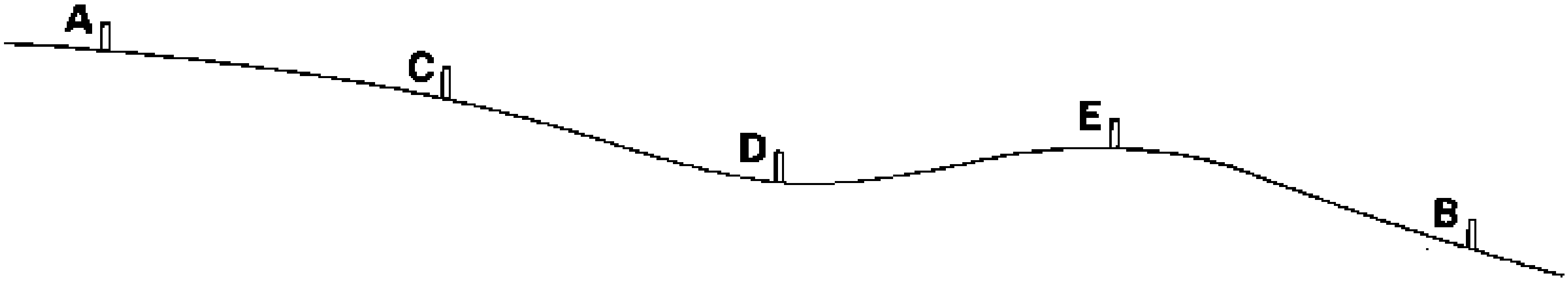

A
20 cm
first contour line (after correction)
B
C
A1

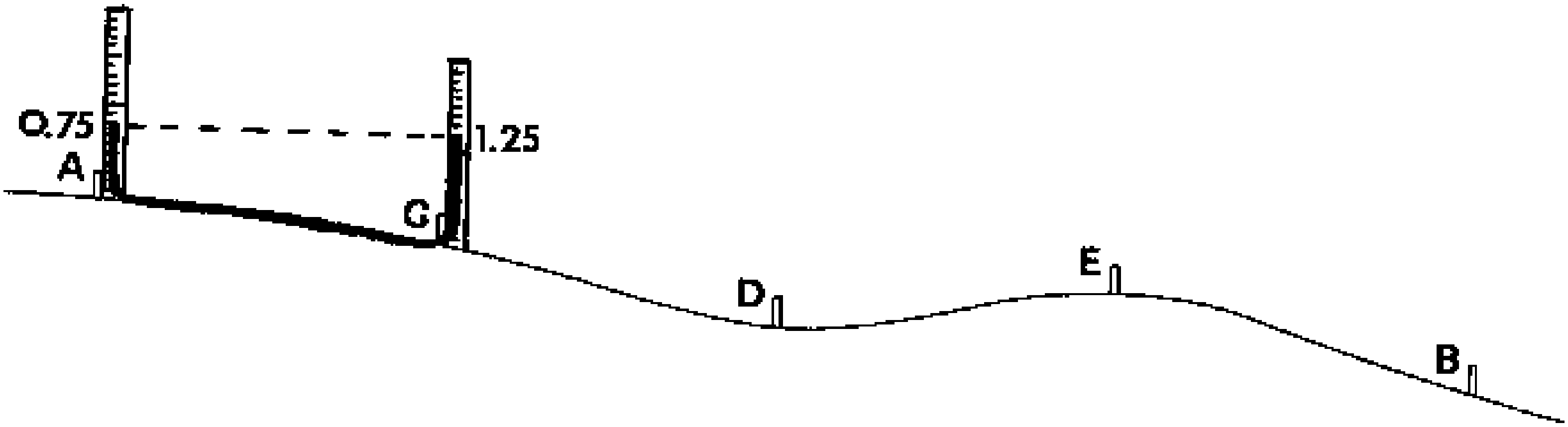

carpenter level
longest leg
90 cm
shortest leg
88 cm
slope 1%
2 cm
200 cm

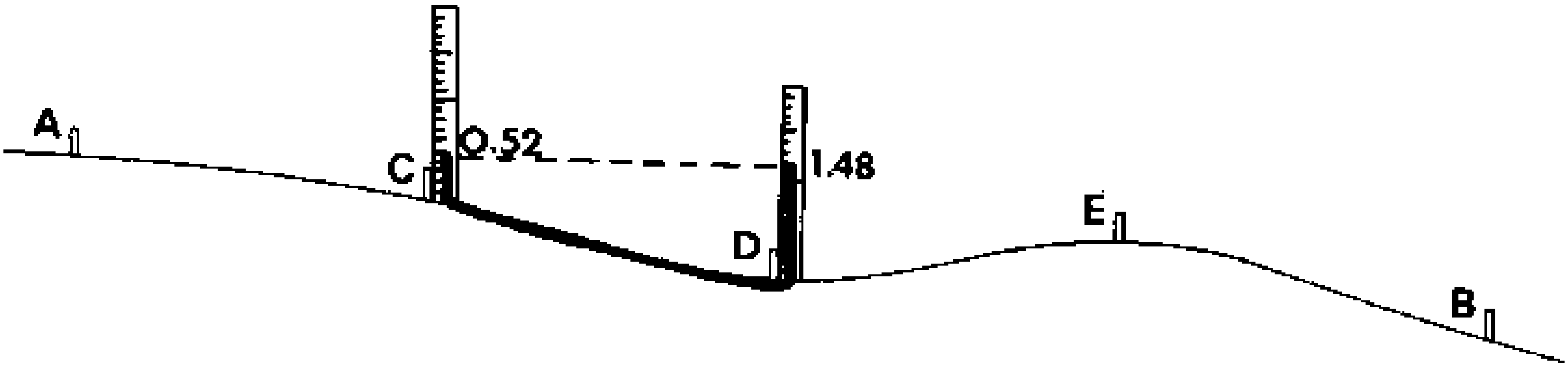

longest leg
shortest leg
A

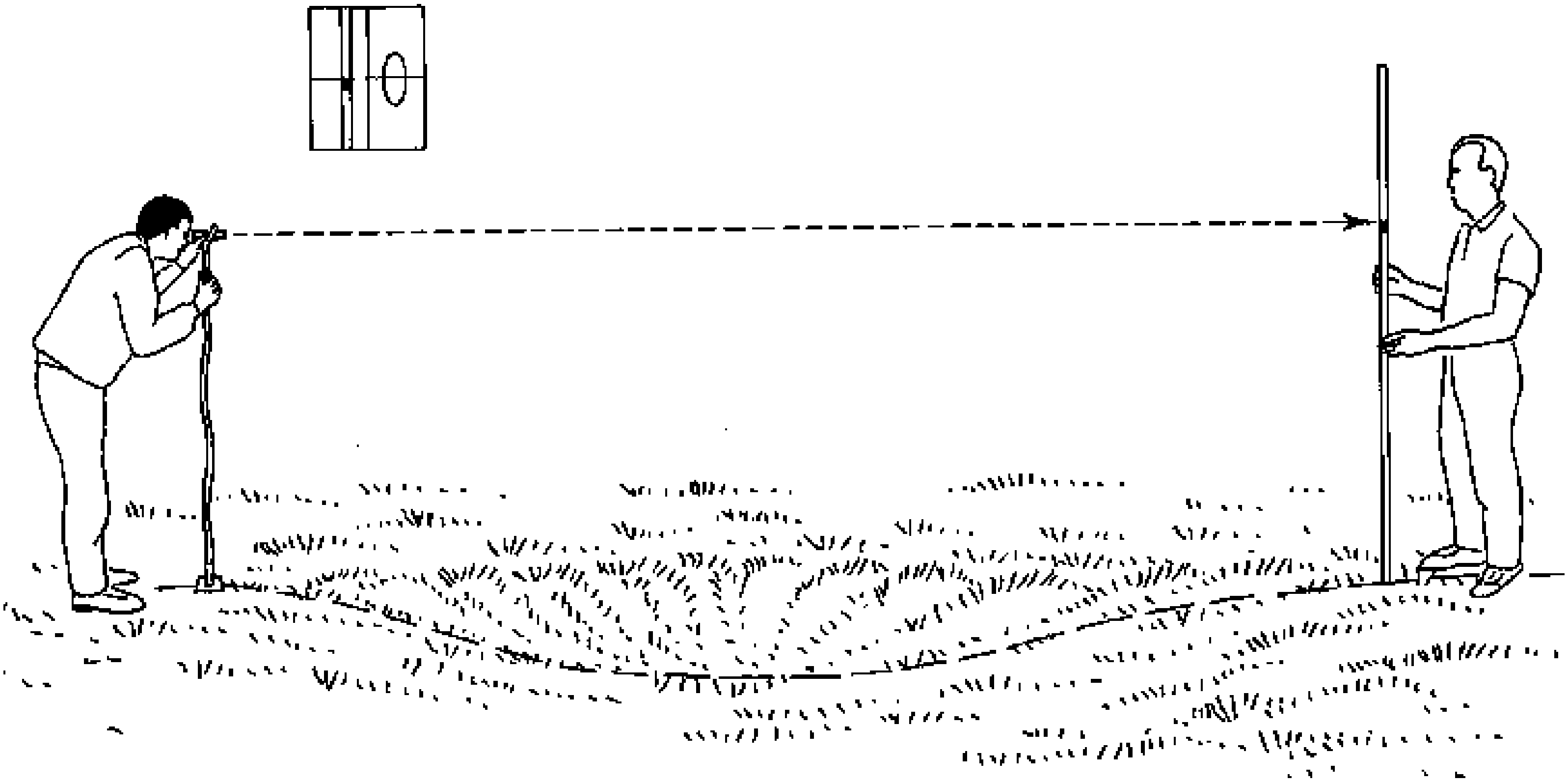

A
B
C
line with slope of 1%
peg D needs a correction
E

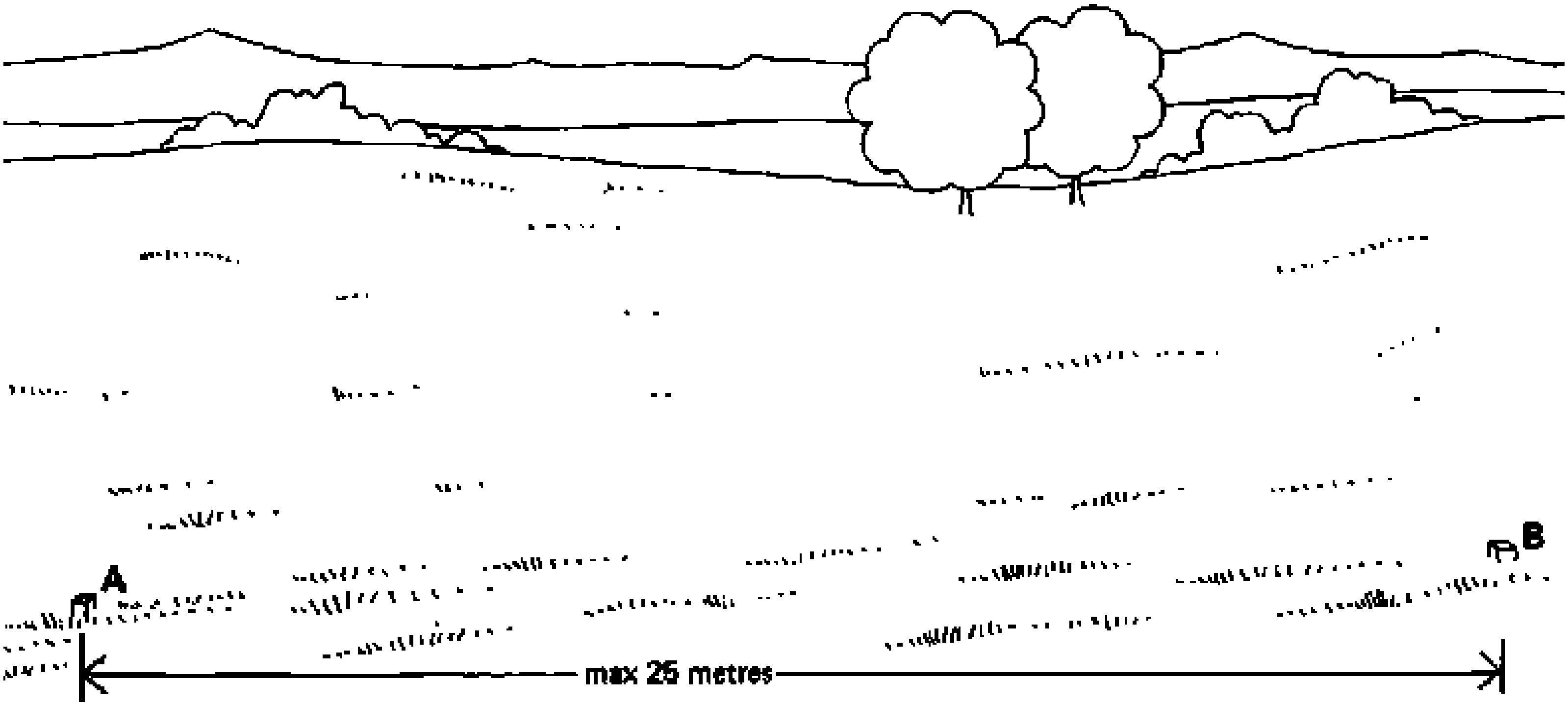

back man
mark
peg
lead man
mark

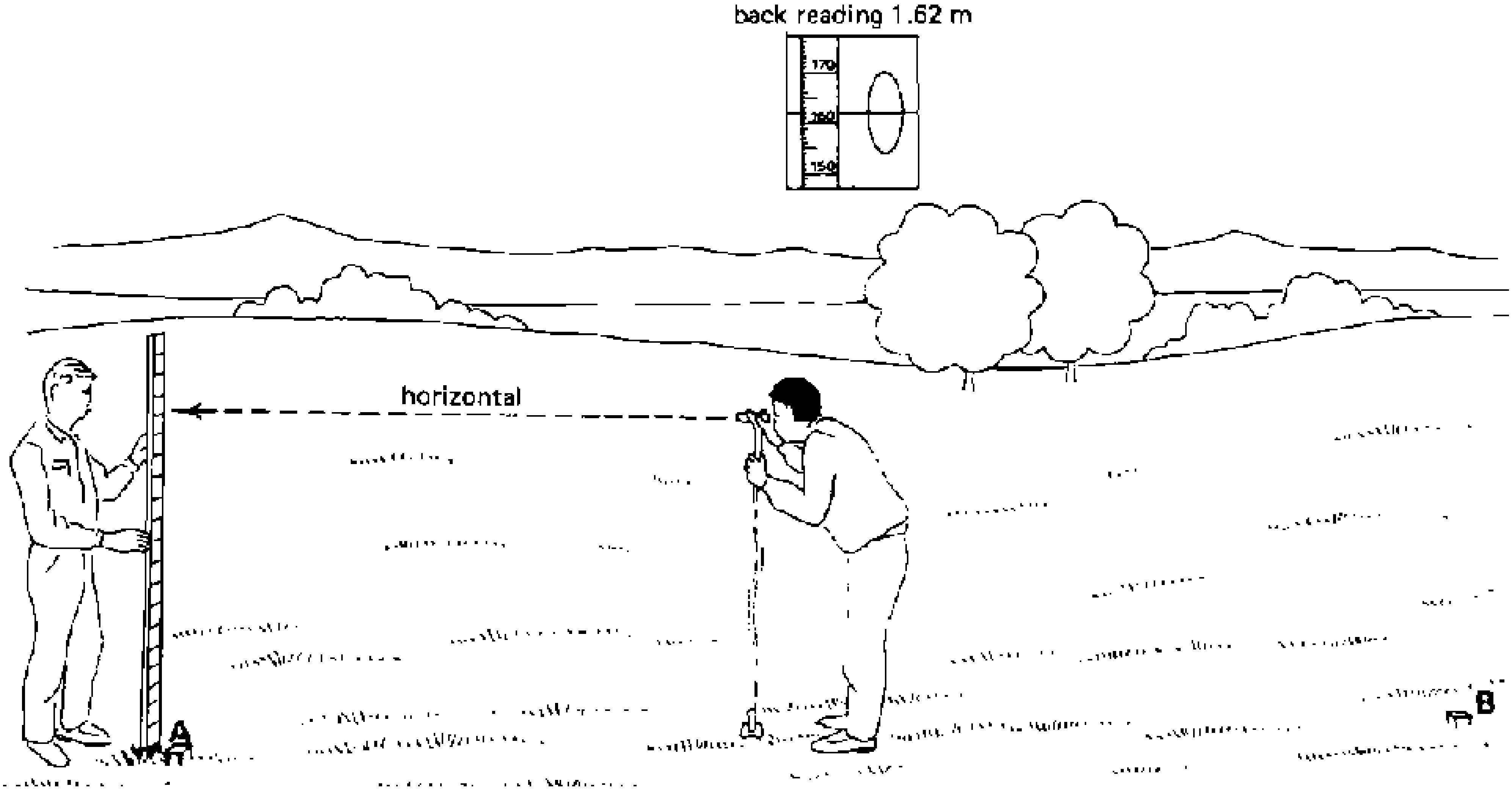

A
C
D
E
B

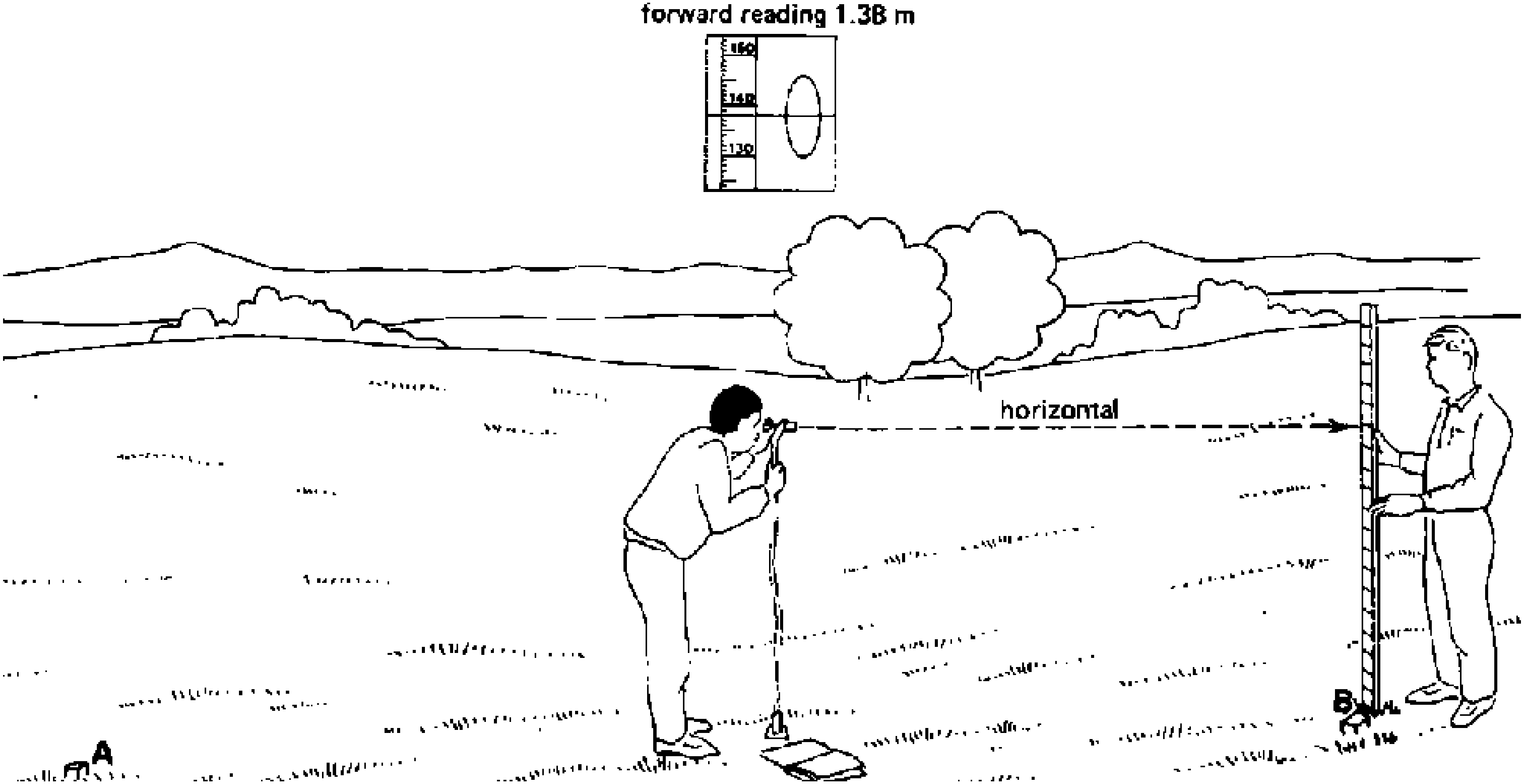

0.75
A
1.25
C
D
E
B

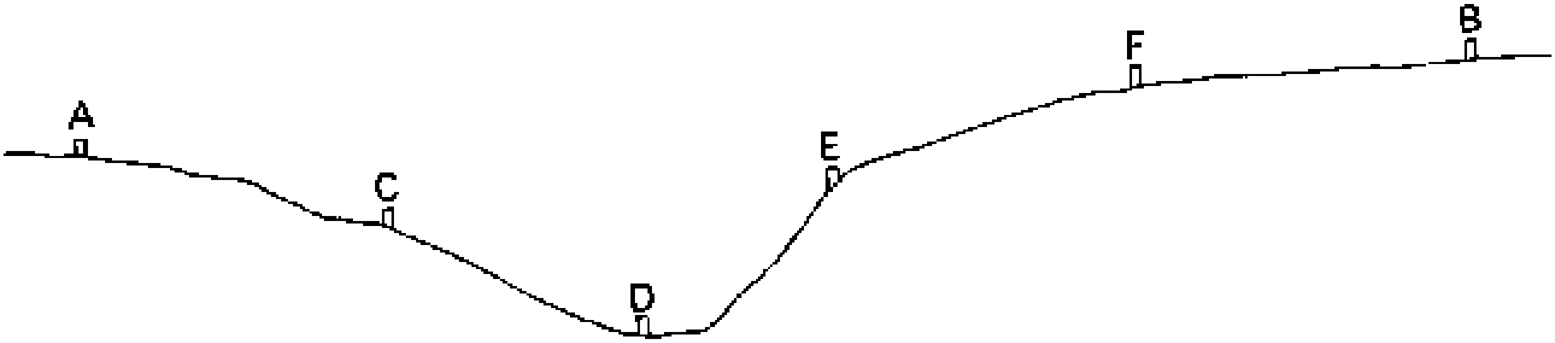

A
C
0.52
1.48
D
E
B




A
B
max 25 metres


back reading 1.62 m
170
160
150
horizontal
A
B


forward reading 1.38 m
150
140
130
horizontal
A
B


A
C
D
E
F
B