NATIONAL SCHOOL
SAILING ASSOCIATION

THE TIMELY ART OF DIALLING

Curriculum Development Paper No 11

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THE TIMELY ART OF DIALLING

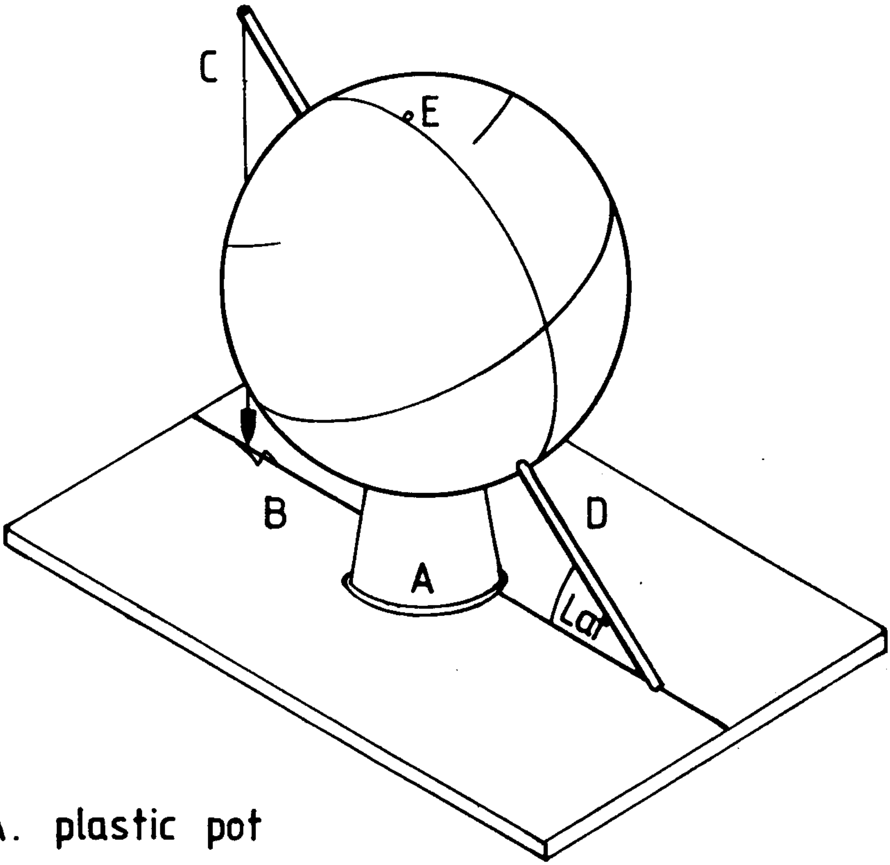
"Twas brillig and the slithy toves
Did gyre and gimble in the wabe".

"The wabe", he explained, "is the grass plot round a sun-dial because it goes a long way before it, a long way behind it and along way beyond it on either side". (Lewis Carroll, Through the Looking Glass).

The art of dialling was once a very important part of mathematics; it is now rarely included in the curriculum, regrettably, since no school should be without its wabe if children are to understand time, its origins, its measurement and its various forms: Apparent time, Meantime, Summertime, Greenwich time, Zone time, Longitude as time, the equation of time and so on.

If you are fortunate enough to possess an old globe dating from the last century the first step in dialling is an easy one. Since, however, modern makers for some reason, refuse to make their globes with an adjustable axis, you will be driven to buy, a cheap globe and adapt it to your use.

The first thing to note is that the axis of the globe should be at an angle to the horizontal plane equal to the latitude of the place in which you are working. Secondly, it should not have too shiny a surface. Figure 1 shows a simple mount, easily made by children; if the lid of a plastic tub is first pinned down to the base board and the upturned tub fitted in place all will be firm and secure. An excellent way of obtaining a surface that will show shadows clearly is to coat the globe with wallpaper paste and cover it with a single layer of surgical gauze. Finally, the place to keep the globe is in a South facing window and not on top of a cupboard and it should be so arranged that the North Pole of the axis points due North.

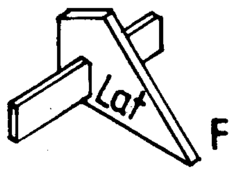


A. plastic pot

B. north - south line

C. plumb line

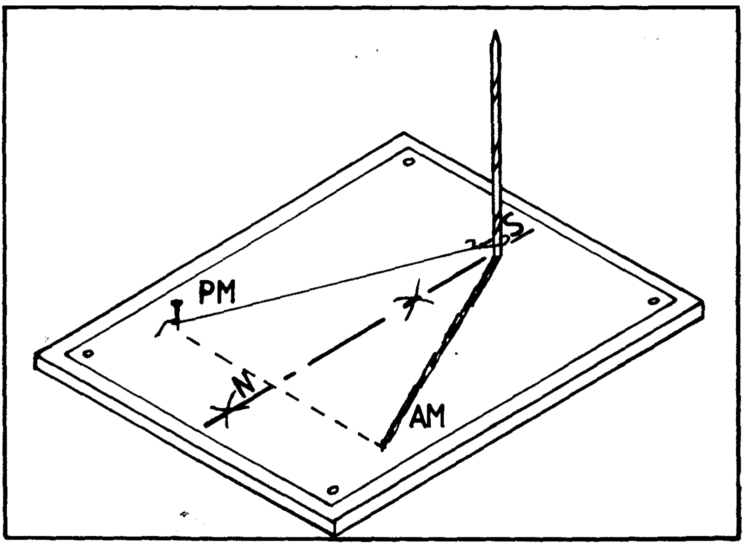
D. axis (wire or dowel)



E. England at zenith

F. latitude measurer

Because of the errors all compasses are heir to (especially indoors with steel radiators, table legs and so on to act as distractions,)it is as well not to trust them for finding North; rather use a shadow stick made from a knitting needle or a wooden skewer. Pin a sheet of paper down in the place you intend to have the globe later on (perhaps on a table in the window); drill a vertical hole into the base board and wedge the skewer into it with the sharp point uppermost. There are advantages in having the hole rather too large and small wedges made of sharpened match sticks to secure the skewer as by this means and with the aid of a plumb-bob or tri-square and spirit level it becomes possible to ensure that it is really upright. Now, mark the tip of the shadow at some time in the morning (the earlier the better) with a piece of string looped over the skewer and a pin stuck through it at the end of the shadow. Wait until the shadow is the same length in the afternoon and mark its tip in the same way. Join these two points and construct a perpendicular bisector which will be found to pass through the centre of the base of the skewer and to point due North and South (See Fig. 2).



The best time of year to start these experiments is during the Summer term. Quite apart from the meteorological advantages, the Sun, being North of the equator will light up to top of the globe where observation is easiest. Set the globe up in its prepared place and use a plumb line to match up with the 180th meridian and the North-South line of the base board. This will ensure that the axis points North and that the meridian of Greenwich is exactly on the front of the globe. If a small triangle of card is cut out with its base angle equalling the latitude, the axis can be matched to it so that the British Isles are in just the right position on top of the globe.

Now set the globe up and, on the first sunny day, a number of things will happen. If you are up early enough, you will find that the Sun rises over England on the globe just as it is rising outside. It will be due South of England on the globe when it is due South of the school. The shadows around the back of the globe will mark off those places in the world which are in night. As the shadow moves round during the day , you will be able to see the Sun rise and set in different parts of the world. If it should happen to be Midsummer day, the edge of the shadow will just reach as far as the Arctic Circle and the rest of the North Polar area will be bathed in sunlight. By looking also at some country in the Southern hemisphere at that time of the year , it will be possible to see:

"What cause delays
"The Summer nights and shortens Winter days"
(Dryden's Translation of Virgil)

If the experiment is carried out in Spring or Autumn, the reason for the names "Vernal and Autumnal equinox" becomes apparent as the edge of the shadow will pass exactly through both poles on those days and the globe will be exactly half lit up and half in darkness, thus producing "equal nights".

Watching the shadow move around during the day will begin to set off questions about time and, if the work is being done during the summer, the children may notice that the shadow of the axis wire moves steadily around the North Pole. It is not difficult to make a small white cardboard disc with a hole in the centre to slip over the axis and so rest upon the North Pole. Thi s w ill show the moving shadow more clearly and marks could be made at hourly intervals, to see whether they are evenly spread. (They will, in fact, be 15 degrees apart). Children will, no doubt, know that "the Sun is South at midday" and will want to mark off a fresh dial accurately with 15 degrees sectors labelled from 0 hours (on the meridian of Greenwich) clockwise to 24hours. One of the first things they will notice about the time this sun-dial tells is that it is about an hour different from that told by the clock. This, of course, is due to the machinations of our political masters who are as determined to get us to work quickly, as they are to get the children to bed early in the evening.

The next step in dialling will probably become necessarx after the Summer holidays when, by September, the Sun is going South of the equater and therefore throws no shadow from the North Polar axis. It would be equally easy to make a second disc and fit it on the axis at the South Pole, but, with the globe in the way, it is difficult to read. On the whole, it is better to start afresh and make another bast board axis, this time without a globe but with a cardboard disc marked on both sides. (See Fig. 3)

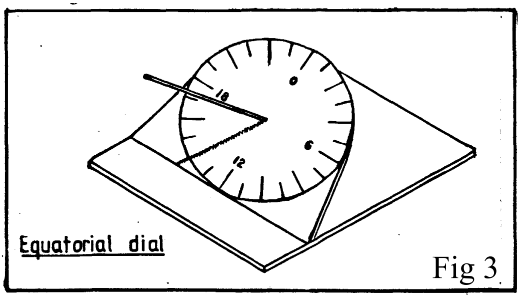


Fig 3

It is worth while making the base board as wide as practicable as it will then also serve admirably for later experiments. The disc should be marked on good, stiff card, set up at right angles to the axis (now called a style) and about half way along its length. Summer shadows will be on the top and Winter shadows underneath the disc. Thus, almost by accident, an equatorial dial has been constructed. There are snags about this particular design, however; for a week or two on either side of the equinoxes, the shadows are faint and difficult to see and, of course, during the winter one has to peer underneath the thing to tell the time. An improvement can however be made with a cylindrical dial . A squeezy bottle, some paper and a knitting needle will serve to make a rough one and plastic drainpipe with scraps of wood will serve for a more sophisticated instrument. (See Fig. 4). First mark out the exact centre of the bottom of the bottle. If it is of the kind which has a small hole in the mouth, the centre of the top is already marked out for you. Next, mark out two lines along the sides so that the bottle can be cut exactly in half while leaving the top and bottom intact. Now make a hole at the centre of the bottom and-push a knitting needle through until the tip enters the hole in the centre of the mouth, thus forming an axis to the -cylinder . Cut a sheet of paper which will exactly fit the inside of the half cylinder and mark it out with Llequidistant parallel lines, labelling one end (the top) North and the other end South. Starting at the Western side, label the lines 7, 8, 9, etc up to 17. The two edges are, of course, 6 and 18 hours respectively. (See Fig. 5 for the geometry). Now fit the paper inside the squeezy bottle, with a dab or two of glue, make a bracket of thick card as shown in Fig. 6 to rest the bottle on and set the whole thing up in the sunshine with the axis pointing due North. At this stage it is as well to remember the tag on so many old sun-dials.

"Set me right and treat me well,
"And I to you ye tyme will well".

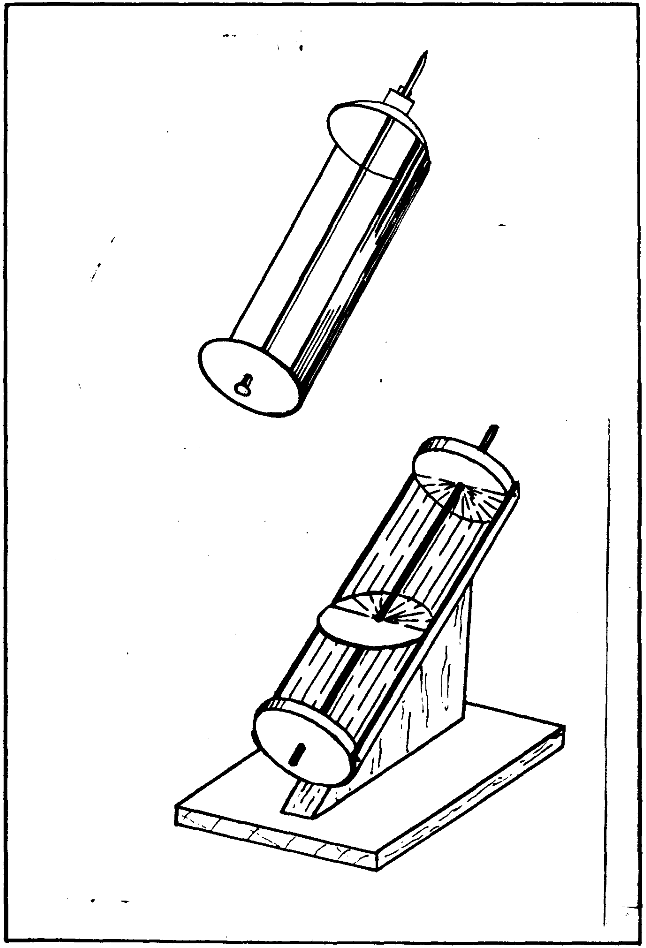
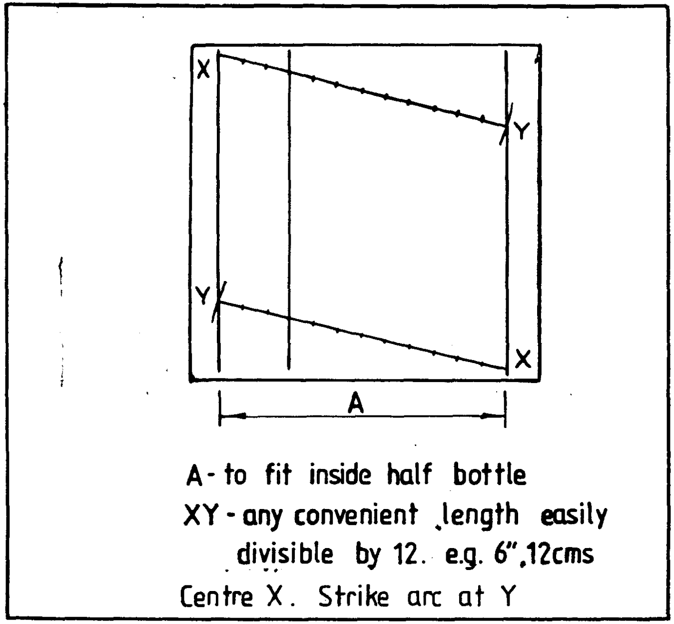


Fig. 4


X
Y
Y
X
A
A - to fit inside half bottle
XY - any convenient length easily divisible by 12. e.g. 6", 12cms
Centre X. Strike arc at Y

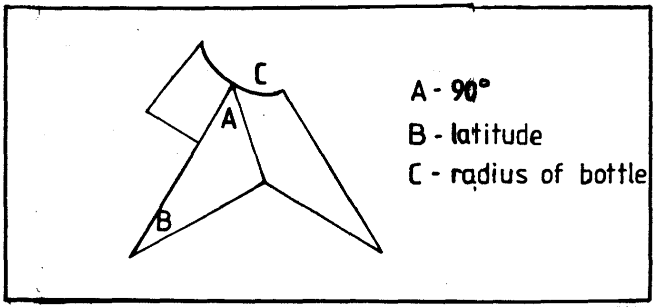

C
A
B
A - 90°
B - latitude
C - radius of bottle

Fig. 6

Having got so far, it is worth taking another and more careful look at the equatorial dial. By about October the shadows on the underside will be clear enough and it will be noticed that the style throws a shadow on the base board as well as on the dial and that these two shadows meet at the dihedral angle between the dial and base (See Fig. 7). By drawing lines from the centre of the dial to given hour marks and producing them thence to the base, the points at the dihedral angle can easily be found. These can then be joined to the point at which the style enters the base board; the markings of a horizontal dial have been discovered by experiment and principles underlying the common or garden dial are laid bare.

Some children might like to experiment by setting up a vertical plane and by dealing with it in the same way, produce a wall dial of the kind sometimes seen on churches. A compound equatorial, common and wall dial can be constructed entirely of card and is really a quite testing piece of geometrical construction (See Fig. 8).

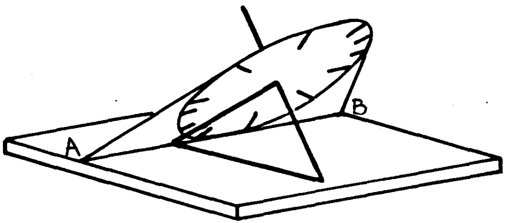
A similar procedure can be adopted with the "drainpipe model" of the cylindrical dial if the children have sufficient geometrical skill to construct an ellipse which will fit exactly and horizontally into the half-cylinder. This too can be marked with the hours where the edge of the ellipse meets the parallel lines . Any boy or girl who has the discipline of the drawing board at, his disposal, may care to take matters further. From the experiment with the cylindrical dial , it will be plain that all fixed dials are sections of a cylinder inclined to the horizontal at an angle equal to the latitude, the cylinder having previously been divided and marked on all surfaces in 15 sectors (See Fig.12). Common or garden dials are horizontal sections and wall dials are vertical sections. Dials designed to be sited on sloping ground or upon walls facing directions other than South, require auxiliary sections upon planes parallel to those on which the dial is to be fitted. In these latter cases, the true slope of the style and its position in space are problems whose solution is both elegant and demanding.

Returning to the exercise the whole thing started with, a globe in the sunshine, some other experiments are worth carrying out. Now that simple equatorial dials are within the children' s competence to make , a number of these can be put together of card, small enough to stick on to different parts of the globe. They will of course, tell the time at eg Bombay, London or New York simultaneously and the connection between longitude and time will become apparent. (See Fig. 9 for a design).

A simple cross of card can be made (See Fig. 10) which, when placed on the globe, can be moved around until it throws no shadow. It will then be at the "sub-solar point" and if it is followed throughout the day , the Sun's path over the earth can be marked out. In March and September, this path will, of course, follow the equator. In July and December however, it will be found to coincide with the Tropics of Cancer and Capricorn.

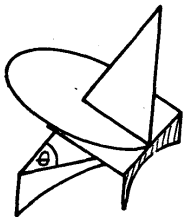
In all this work with dials, however, two points of interest will have emerged: the varying height of the midday sun and the varying difference between Mean and Apparent time (even after allowance has been made for the hour filched from us by our legislators).

It is worth making a further instrument for investigating these phenomena: a shadow square (See Fig. 11). This is simply two' planks glued together at right angles . It should be accurately done and the edges should be parallel and straight. The inner face of the vertical plank can be 10 cm high and the horizontal one about 60 cm , so that it will contain long Winter shadows.



AB dihedral angle
AB dihedral angle measured here = 90^{o} - Latitude

Fig. 7



Card equatorial dial for globe
Curve edges to fit globe
θ = Latitude of places to be fitted

Fig. 9

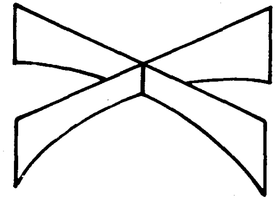


Fig. 10

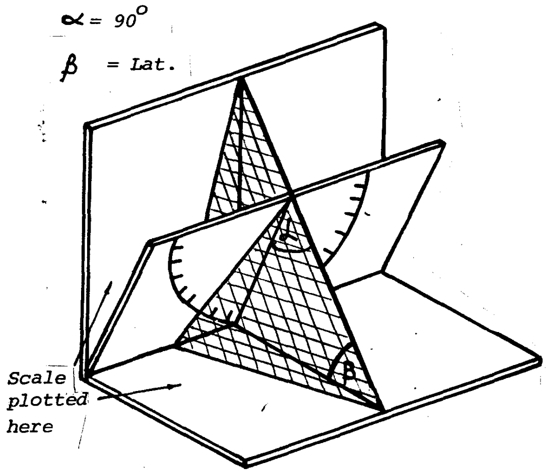


Fig. 8

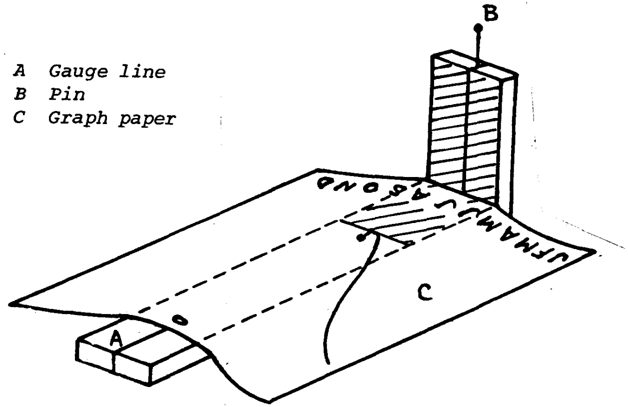


Fig. 11

To keep a continuous record throughout the year of the Sun's altitude, a sheet of graph paper should be prepared and dated along one axis while being labelled in centimeters along the other. This is then pinned to the horizontal plank with the date line matching the gauge line and the shadow tip marked at midday. Repeated from time to time throughout the year, the graph will be completed. Able children using the length of the shadow in decimeters as the tangent of the zenith distance (or the co-tangent of the altitude) may wish to convert their results into degrees of arc; others will be satisfied to make scale drawings and read off the angles with a protractor . The results are, in any case, worth graphing so that a year's re- cord of the varying zenith distances (90^0 - altitude) is available for study. The children may be interested to find that their curve is a typical harmonic wave and that if they draw horizontal lines across the graph from the peak and the trough, then bisect the distance between them they will obtain a mean figure for the year. They may be surprised to find that this corresponds with the latitude of the place they are working in. If they count the number of degrees above and below this centre line and make a fresh scale on the other edge of the graph paper, they will find this provides a record of the Sun's declination throughout the year and that its limits are 231° North and South. The children will enjoy comparing their figures with the predictions in an almanack to see if the Astronomer, Royal has got his sums right.

Similarly this instrument can be used to measure the equation of time with some precision. So far, only a comparison of the, clock and the dial at midday has shown this difference,but, by' timing equal altitudes, morning and afternoon, their average will give the mean time of apparent noon, and after making) allowance for B . S .T . , the difference between that and 12 hours will give the equation of time (also worth comparing with an almanack).

The most accurate results will be obtained if the shadows are long ones, early in the morning and late in the evening as they then change their length quite rapidly and timing is more precise.

These exercises can be carried further and a variety of nocturnal dials can be made to tell the time by the stars. They depend upon the use of the "pointers" of the Great Bear as the hour hand of the sidereal clock and by rotating the dial itself to match the time of the year, sun time can be deduced.

"Practical Astronomy" by Schroeder has a good description.,

Pocket dials which depend upon a compass needle inside them for orientation are simply small and portable common dials. Those which depend upon shadow length are more complex in their geometry since they require time scales for different times of the year. They are not difficult to make by experimental methods but geometrical constructions from first principles is probably beyond most children. Before attempting a portable dial that needs no orientation, it might be as well to carry out some further experiments with the shadow square: Pin a fresh strip of paper on the horizontal leg at the start of each month and mark the length of the shadow at hourly intervals. If this is done two or three times during the month the "average" strip could be regarded as "typical" for that month and used in future for telling the time . In practice, the months I will be found to go in pairs. June, May and July, April and August, March and September, Febrary and October, January and November, December. One strip will serve for each pair of months with separate ones for June and December.

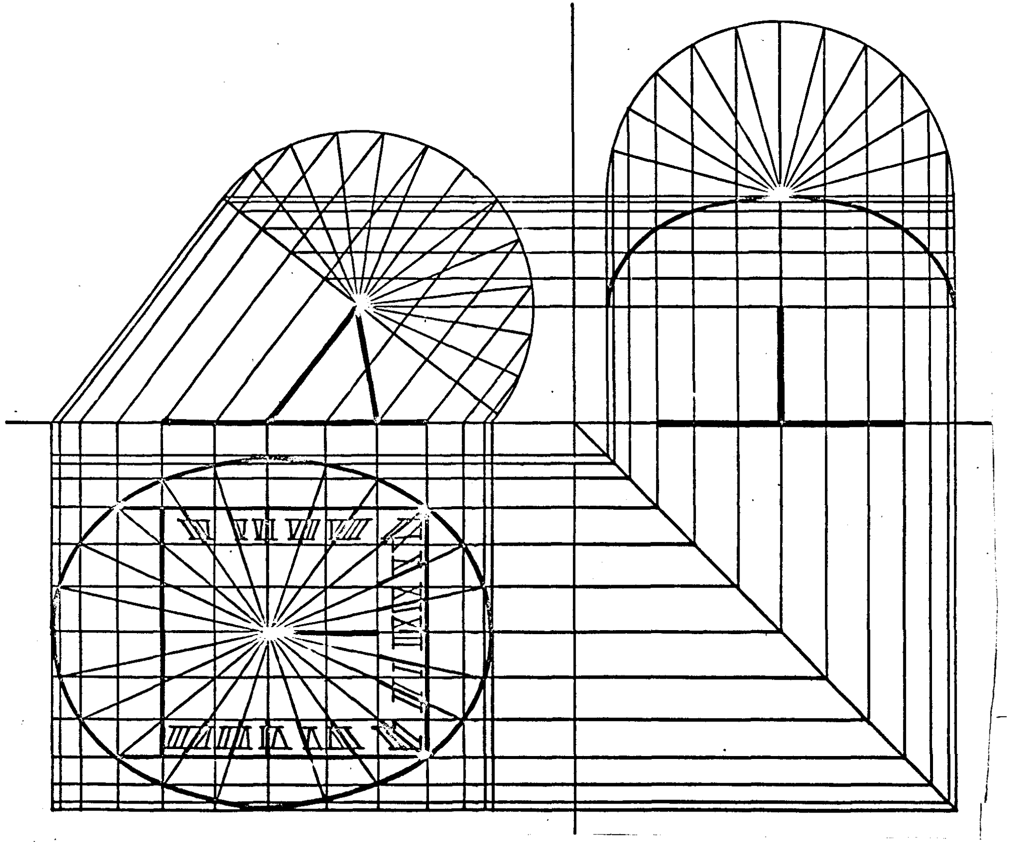


Fig. 12

A common dial projected as the horizontal section of a cylinder inclined at an angle to the horizon equalling the latitude of London (52^{o})

Portable Dial
A Paper clips to hold paper sleeve together while marking out
B Gnomon
Note: It is September. The dial is turned to get a vertical shadow
The sleeve is turned until the shadow touches the September curve
The time is 11 or 13 hours

Fig. 13

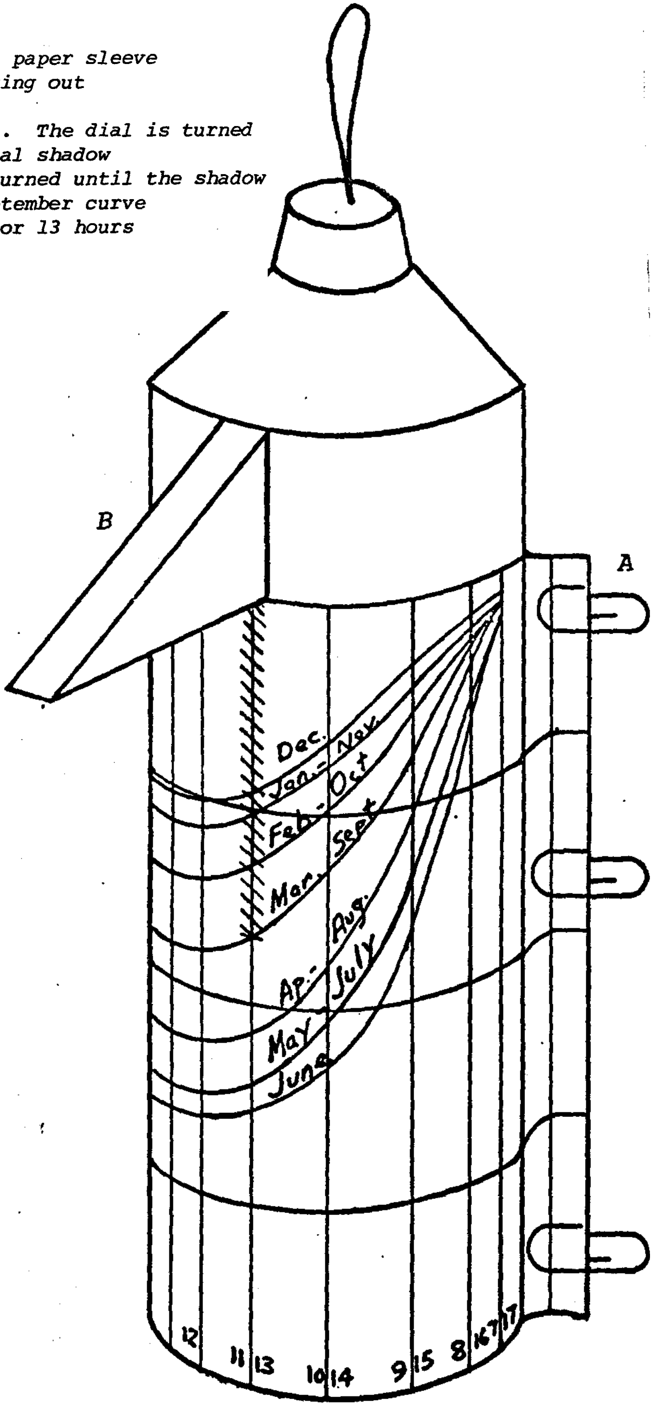


Figure 13 shows a simple portable dial made from the essential squeezy bottle. It needs ballasting to hand vertically and the best material for this is jelly, poured in hot to about half-way up and then allowed to set with the bottle standing upright. The style, three or four inches long can be made of a scrap of wood or plastic and glued on. It is important that its base coincide with the vertical line of the bottle and that it have a nice sharp chisel edge. The sleeve of graph paper must be free to turn and is best clipped together rather than gummed into a cyiinder, at least until all the marking out is completed.t As with the shadow square, a date at about the middle of each' month is chosen, the dial is set to cast a vertical shadow, the, sleeve rotated till the hour line under the shadow matches the' clock and a mark is made at the tip of the shadow. By the end of the day, there are enough points to join up into a fair curve,, to be labelled "March" or "October" as the case may be.

Once the curves have been drawn, the sleeve can be gummed up (though still free to turn) and telling the time is straightforward. Set the dial to get a vertical shadow, revolve the sleeve till the appropriate month line touches the tip of the shadow and the hour line at that point will tell the time. In Fig. 13 the date is September (or March) and the time 11 or 13 hours.

Children who have clever fingers could devise a pocket model with a folding style and the two parts of the cylinder revolving on a common axis thus removing the need for a sleeve.

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