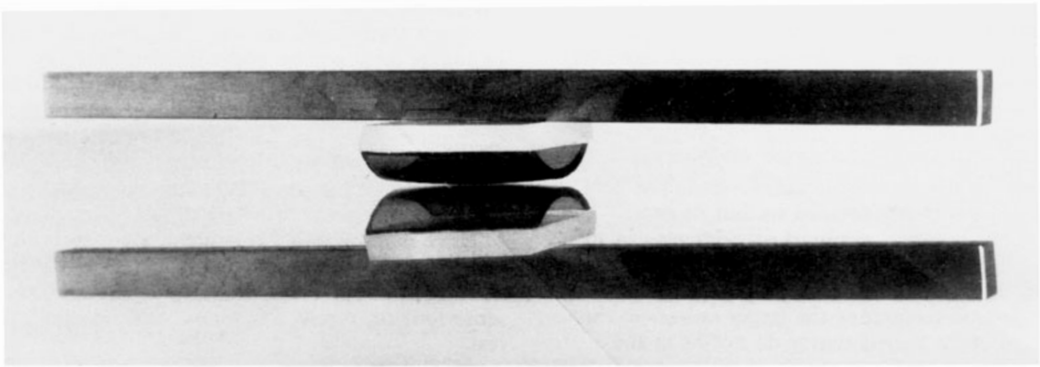
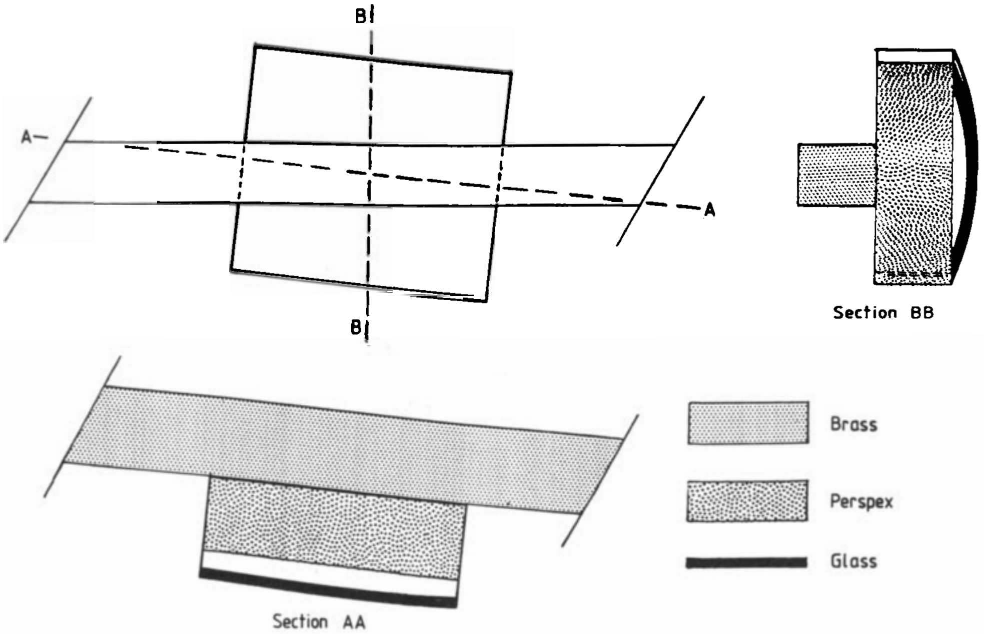
Letters and comments

How to make a celt or rattleback

Crabtree, in his book (1909) on gyroscopes, describes how certain prehistoric flint tools, which he refers to as celts, may behave in different ways when spun on a smooth surface. They may readily



(a)



(b)

Figure 1. (*a*) The rattleback resting on a glass plate and photographed at a glancing angle, so that the reflection enables the curvature to be appreciated. (*b*) A plan (top left) and two sections of the central portion of the rattleback, the brass inertia bar being truncated.

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spin in either sense, or they may refuse to spin in one sense and wobble violently while reversing to the preferred sense (the toy marketed in the USA under the name of Rattleback is of this sort): or they may refuse to spin either way, and reverse sense whichever way they are started. Crabtree refers to the theory by Walker (1896), but recently Bondi (1986) has investigated the problem more thoroughly and determined the conditions for the different modes of behaviour to occur. The phenomenon is at first sight shocking to physicists who have become over-confident about their understanding of classical dynamics, and its demonstration to students consequently imparts a valuable lesson, even if they never manage to master the theory involved. This letter describes an easy way to make a model which can be shown on an overhead projector. Since the essential part, which is otherwise the most difficult to make well, is a portion of a wine bottle there is every reason to take pleasure in the construction.

An example of the finished device is shown in the figure 1(*a*); it is no more than an inertia bar provided with a base on which to spin. The base must be smooth and shaped so that its two principal curvatures are markedly different – in this example the principal radii are about 3.5 and 25 cm. The bar is fixed at a small angle (6°) to the plane section containing the larger radius, so that the axes of the inertia tensor do not lie in the principal planes of curvatures of the base; it is this dynamical skewness that generates the peculiar properties. It is also desirable that there should be fairly strong sliding friction between the base of the spinner and the flat surface on which it rests, so that the spinner shall roll rather than slide, and generate the frictional forces which are responsible for the strange behaviour. At the same time the materials should be hard to minimise the area of contact and hence the frictional damping of rotation. These conditions are well met by making the base of glass and spinning on the glass plate of an overhead projector.

A bottle that had held Rhine wine was used. There is a zone in these slender and gently tapered bottles, just above where the taper begins, where the curvature in the vertical plane, as judged by eye, is fairly constant for about 4 cm. This zone was first cut out by two horizontal cuts of a diamond saw, and then divided into four by vertical cuts (two of those cuts were made along the mould marks which are the only blemishes on otherwise ideal surfaces). The edges of one of these quadrants were then ground flat so that a $\frac{1}{4}$ in (6 mm) plate of perspex could be attached by superglue, and finally the brass inertia bar was fixed to the top of the plate by superglue. This provides a rigid demonstration model, but for private study it is better to hold it by a single bolt so that the angle at which it is set and the height above the base are readily adjustable. The inertia bar shown in the picture is of brass, 26 cm long and of 12 mm × 9 mm cross section. The centroid, which of course must not be above either of the two principal centres of curvature, is 23 mm above the base, about $\frac{2}{3}$ of the smaller radius. None of the dimensions is critical, but the best results seem to be obtained by using a long inertia bar, though not so long that it hits the plate when the spinner begins to wobble.

There is no need for rapid spinning which only encourages slipping when the wobble starts. After starting at about 1 rev/s the spinner may reverse sense four or, rarely, five times before coming to rest.

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References

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