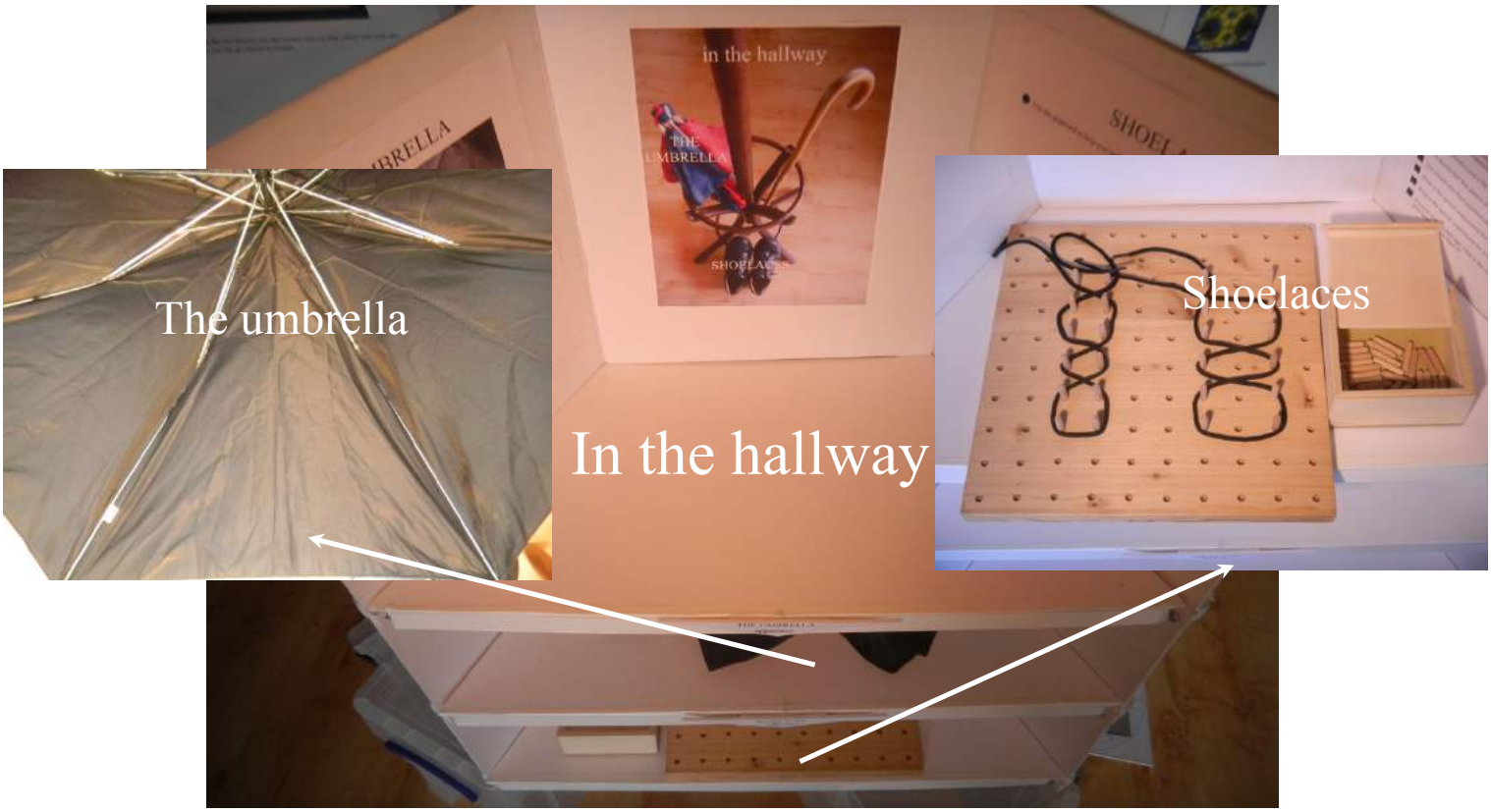


THE UMBRELLA

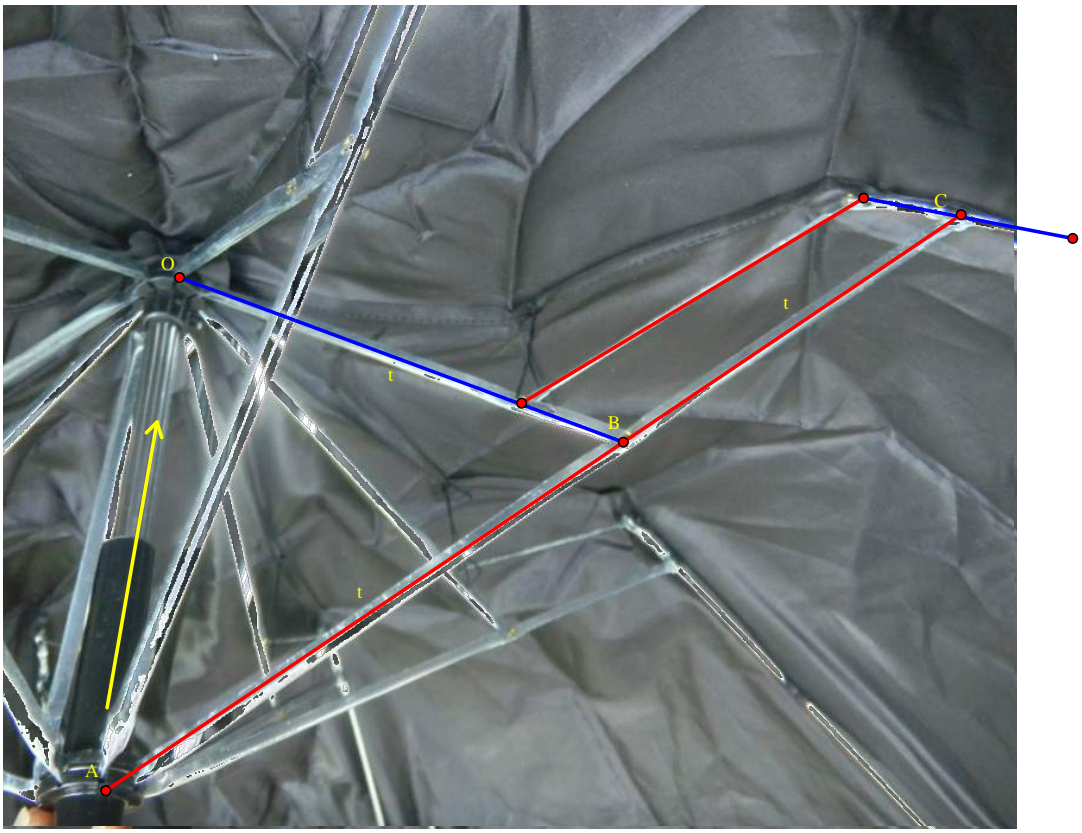
What 2-D shapes can you identify?

How can they change?

How are they connected?

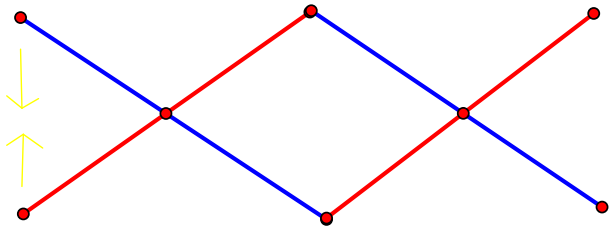
What is their function?

Notes



Parallels are shown by colour. The user pushes the yellow slider in the direction of the arrow. We observe the apex of the isosceles triangle formed on this base to move outwards (describing a circle about the head of the umbrella), the parallelogram to open out, and the blue lines to separate. But we can say more. If the lengths are as marked, we have a circle centre **B**, diameter **AC**, passing through **O**. Angle **AOC** is therefore a right angle, which means that the locus of **C** is a straight line perpendicular to **AO**.

If the other side of the parallelogram was joined to the slider, and the parallelogram was a rhombus, we would have a pair of 'lazy tongs':

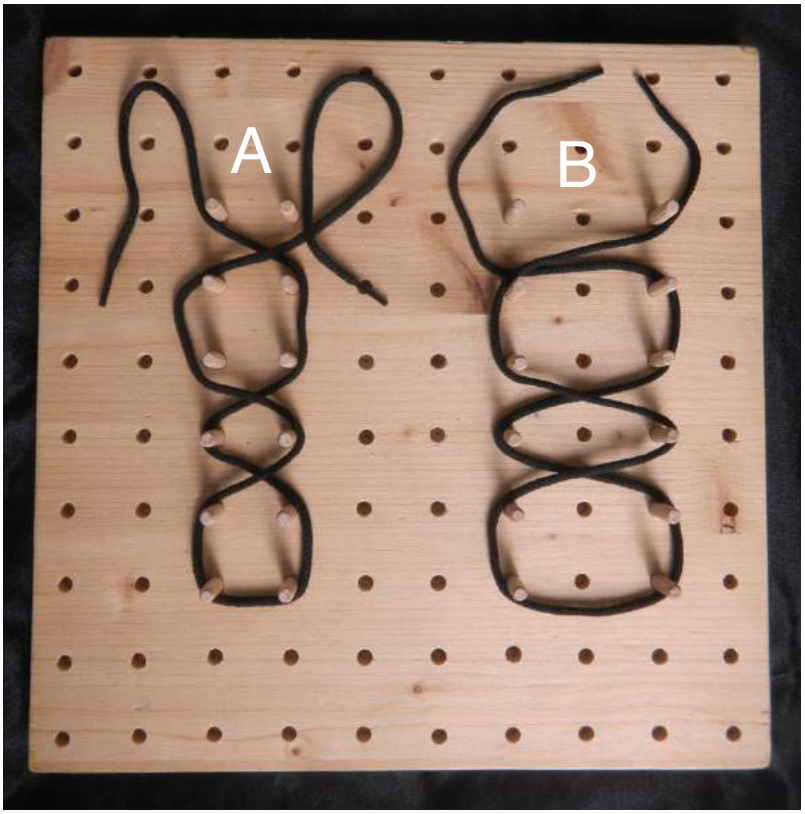


An index of mobility, describing the variety of positions into which it can be moved, can be defined for anylinkage. The 'degree of freedom' is determined for each part, and a sum formed for the whole. Go to en.wikipedia.org/wiki/Linkage_(mechanical) . If we make the calculation for the umbrella, we get a mobility of 1. This makes sense if we consider the point **C**, which is confined to a straight line, representing a single degree of freedom.

For a first sketch of a morning workshop for 13-14-year-olds on the subject, e-mail me at the address below.

SHOELACES

Use the pegboard to help you tackle these questions.



What do laces do?
What do laces do that velcro doesn’t?

What makes for a strong lacing pattern? [1]

Does it make a difference whether the horizontal spacing is close [A] or wide [B] compared with the vertical separation?

Which pattern(s) use(s) the shortest lace? [2]

You should find that pattern is/those patterns are, symmetrical. Why is this?

You should also find requirements 1 and 2 conflict. What compromise solutions are possible?

What is the special requirement for a soldier's boot? Which pattern(s) meet(s) it?

What is the special requirement for a footballer's boot? Which pattern(s) meet(s) it?

If you're wearing lace-ups, what is the requirement for your shoes today? Look down! Does your lacing pattern meet it?

Notes

What do laces do?

They enable the shoe to conform to the foot within an adjustable tolerance so that, on the one hand, the shoe does not slip when the foot moves; on the other, it is not painfully tight.

What do laces do that velcro doesn't?

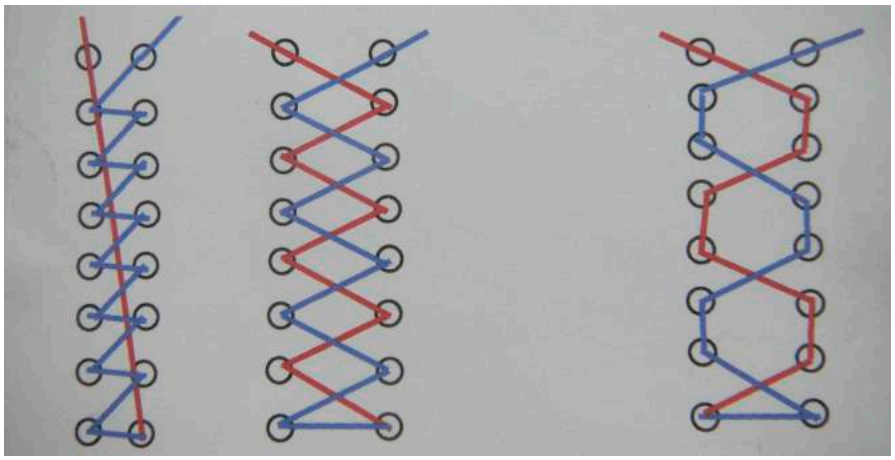
Unless it is hand made, a shoe does not follow the contours of an individual foot. Friction at the lace holes allows the lengths of lace between the holes to vary, achieving that match. Unlike a fastening with buckles or velcro, this variation is to some degree self-adjusting.

What makes for a strong lacing pattern? [**1**]

The tension should have the greatest possible horizontal component.

Does it make a difference whether the horizontal spacing is close [**A**] or wide [**B**] compared with the vertical separation?

*Yes. It turns out that pattern **X** is strongest in case **A**; **Y** in case **B**:*



X ***Y*** ***Z***

Which pattern(s) use(s) the shortest lace? [**2**]

In the 'trivial case' the laces would just run up each side. ***Z*** *has enough crossing-points to give a strong result while using a reasonably short lace.*

You should find that pattern is/those patterns are, symmetrical. Why is this?

Were the pattern asymmetric, the mirror image would also give the shortest result. For there to be a single minimum the two lacings must be one and the same.

You should also find requirements **1** and **2** conflict. What compromise solutions are possible?

Z *is one possibility. Of the 42 patterns described on 'Ian's shoelace site', quoted below, almost all are such compromises.*

What is the special requirement for a soldier's boot? Which pattern(s) meet(s) it?

If the foot is injured in battle, the boot must be removed promptly, preferably by a single cut. ***X*** *is one lacing which allows this.*

What is the special requirement for a footballer's boot? Which pattern(s) meet(s) it?

The part of the boot which scoops up the ball should be free of lace. See which of Ian's lacings has a gap at this point.

If you're wearing lace-ups, what is the requirement for your shoes today? Look down! Does your lacing pattern meet it?

'Ian's shoelace site' (www.fieggen.com/shoelace/) contains, or has links to, everything of importance on this topic. This includes reference to a paper which appeared in Nature vol. 420 p. 476, studying the effect of changing all the parameters we have been considering and more. There was a synopsis jn the 4.12.02 issue of New Scientist.