The origin of the clockwork-escapement

SIR—Scrutinizing accounts of the towns of Cologne, Aix-la-Chapelle, Wesel, Arnhem, Bruges, Deventer, Ghent, Leyden, Nijmegen Rotterdam and Zutphen in the fourteenth century (transcribed and edited in the nineteenth and twentieth centuries)[1–6], I was struck by the frequency with which crossbow makers doubled as repairers of mechanical clocks. Other sources[7–10], which refer to Ragusa and Lille, even mention the crossbow maker as the first local maker of a clock for the town. It is easy to ascertain from these accounts, which refer to the repairs and purchases of clocks, that these were in fact mechanical clocks[10].

On further reflection, it struck me that both mechanisms under the care of this craftsman had one function in common: the capacity to store mechanical energy which can be liberated at the required moment. In the crossbow, this is effected by the released nut, in the clockwork by the escapement.

In the crossbow (Fig. 1) the nut is kept in a locked position by the trigger (Fig. 2*a*). By pulling the trigger the nut is set free. The force of the tight bowstring causes the nut to revolve around its axis,

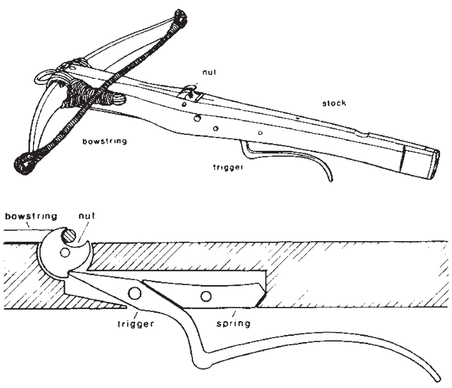

Fig. 1 Crossbow and detail of lock showing how the tight bowstring is kept in position by the nut.

leaving the bowstring free to accelerate and to push the bolt on its way (Fig. 2*b*).

Several versions of the clockwork-escapement exist. The best known of these is the verge-escapement, but it is not certain that this is the oldest type. The lesser-known 'semicirculus' escapement may well be older. We do know, however, that before Huygens, the oscillating element was not the swinging pendulum, but a foliot (literally, little fool) — a sort of torsion pendulum.

In the verge-escapement of the clock, the resistance of the foliot is transmitted to the crownwheel by the two pallets on the verge. The force which the crownwheel alternatively exerts on the pallets turns the verge, freeing the crownwheel to rotate under the influence of the force of the

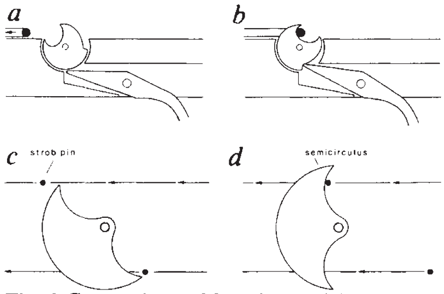

Fig. 2 Comparison of function and form of the crossbow-nut (*a*, *b*) and the semicirculus (*c*, *d*).

falling weight, which is transmitted to it via a train of gears.

In the semicirculus escapement, the resistance of the foliot is exercised by the semicirculus on the strob pins, mounted on a strob wheel. The force of the falling weight, exercised on the strob wheel via a train of wheels, makes the semicirculus revolve around its axis, freeing the strob wheel to proceed (Fig. 2*c*,*d*).

North[11], who was able to reconstruct this early type of escapement on the basis of the text of Richard of Wallingford[12], later discovered that it had been drawn by Leonardo da Vinci. In addition, he suggested that 'rota strob' is derived from *stroba*, Latin for crossbow[13]. This was surmised from the resemblance of the cross-shape of verge and foliot to the shape of the crossbow[14]. It must be remarked, however, that the use of *stroba* for crossbow does not occur in Latin sources until the fifteenth century.

It can, in any case, be concluded that there is an obvious similarity of function between the crossbow-lock and the clockwork-escapement mechanisms. In both instances, energy is released by a revolving containment mechanism, which is moved by the force that is liberated. There is also a similarity of form of the crossbow-nut and the semicirculus, which was pointed out to me by Professor Sleeswyk. In principle, the shape of the semicirculus is identical to that of the crossbow-nut, the only significant difference being the angle of the opening (Fig. 2).

The functional and morphological resemblance between the lock of the crossbow, with its nut, and one of the first escapement-mechanisms, with its semicirculus, is, once noticed, too obvious to be ignored. The shape of the semicirculus is as suggestive of the part the crossbow-nut may have played in the development of the clockwork-escapement as is the double employment of the crossbow maker.

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Physics and Fermat's last theorem

SIR—Surprisingly, Ian Stewart's description of Percival and Vivaldi's application of the theory of ideal classes to chaotic dynamics (*Nature* **329**, 670–671; 1987), is not the only link between Fermat's last theorem and a problem arising in a physical context. A second unrelated and even more immediate connection was discovered recently by D. S. Rokhsar, D. C. Wright and myself (*Phys. Rev. Lett.* **58**, 2099–2101; 1987) in the theory of quasicrystals, a subject familiar to readers of *Nature*.

Kummer's great work in the 1840s, referred to by Stewart, turns out to bear directly on the problem of classifying quasicrystallographic diffraction patterns. The first step in such a classification scheme is to re-examine the fundamental enumeration by Bravais of the possible lattices of wave vectors, in the absence of the traditional crystallographic constraint that there should be a minimum distance between points. To begin such an extension of classical crystallography, one must first solve the two-dimensional lattice problem.

Two-dimensional lattices can be viewed as the ideals of the algebraic number fields called cyclotomic integers. The number of crystallographically distinct classes of such lattices with *N*-fold symmetry, (N=4,6,8,...) is just the number of ideal classes in the cyclotomic integers of degree *N* (or degree *N*/2, if *N* is twice an odd number). This number is unity, for all values of *N* less than 46, and before the connection with algebraic number theory was realized, it was hard to resist the