Edme Mariotte and Newton's Cradle

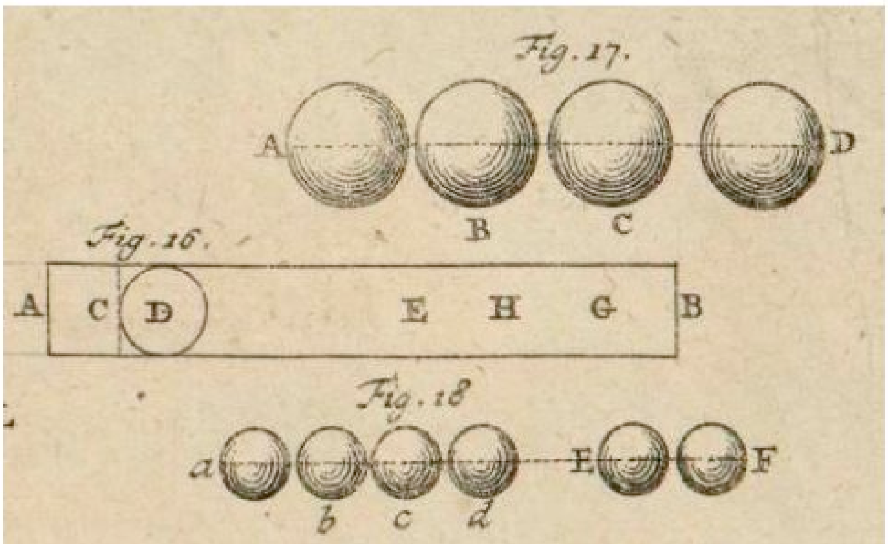
The first recorded experiments describing the phenomena made popular by Newton's cradle appear to be those conducted by Edme Mariotte around 1670. He was quoted in Newton's Principia, along with Wren, Wallis and Huygens as having conducted pioneering experiments on the collisions of pendulum balls. Each of these authors concluded that momentum (then described as the "quantity of motion") is conserved when one ball collides with another.

Mariotte's collision experiments were presented to the French Academy of Sciences in 1671 and subsequently published in 1673 as "Traité de la percussion ou choc des corps" . The treatise was included in a larger volume of his work, titled "Oeuvres de Mr Mariotte", published by the Academy in 1717, describing his discovery of the blind spot in the eye and the relation between pressure and volume for gases, as well as many other studies on plants, planets, strength of materials and fluid mechanics. [1-3]

Newton was inadvertently credited with the modern version of the executive toy that bears his name, and it is still being described as "Newton's cradle" even by physicists[4]. It is interesting to read the original account of the experiments conducted by Mariotte and his explanations of the effects observed. Unfortunately, the original 17th Century French treatise appears not to have been translated into English. Mariotte's short account of his ball chain experiments is translated here by the author into a slightly modernised English version in the interests of clarity. Figures 17 and 18 referred to in the text are those published in the 1717 edition of Mariotte's work. That edition can be found in rare book collections, and is also available digitally on line (pages 66 to 68 are translated below) at

http://imgbase-scd-ulp.u-strasbg.fr/displayimage.php?album=518&pos=66

PROPOSITION XXVIII



Figures 17 and 18 reproduced from the 1717 edition of "Oeuvres de Mr Mariotte"

Let A, B, C, be three identical balls of ivory or other hard material, aligned as in Fig. 17. Another identical ball D of the same material impacts ball C, along the line AD joining their centers. Balls C and B remain at rest after the collision. Ball D also comes to rest. Only ball A comes forward, with the same speed as ball D before the impact. Regardless of the number of balls, either two or three or four etc only the most remote ball will be set in motion.

If two balls E and F are touching, and collide with several balls in contact such as a, b, c, d in Fig. 18, along the line of direction aF, then the two balls E and F stop, and the others will also remain at rest, excepting the last two a and b, which advance together with the same speed as the two balls E and F.

If there are three incident balls, only the last three a, b, c, advance with the common velocity of the three incident balls, and all the others remain at rest. The number of balls that emerge is always equal to the number of incident balls.

To explain these effects, we can consider the three balls A, B, C, as if they themselves do not touch, and that there is a small distance between them. In that case it is evident by the sixteenth Proposition, that when ball D strikes ball C, it will transfer its speed to C and come to rest. Ball C will then give its speed to ball B, and hence to ball A, and similarly if there are more than three balls.

The same should happen when the three balls A, B, C, are touching. For, by the consequence of the foregoing, the ball C being struck, being adjacent to ball B, will transfer the impact to B. Consequently balls B and C will separate and the same effect will ensue if ball C was not touching ball B, at the time of impact.That is, ball C takes the speed of the ball D, and the result is given to ball B, and hence to ball A, for the same reasons. When there are more balls, the last ball takes away the speed of ball D, all the others remaining at rest. What we find is consistent with experience. If one ivory ball collides with two or three identical ivory balls that are touching, the impact is transferred directly to the last ball, by means of the mechanism first proposed.

We can prove the same for balls E, F and a, b, c, d. If they were slightly separated from each other when ball E collides with ball d, then ball d would take the speed of ball E, and that speed would be given to ball c and so on till ball a, by the sixteenth Proposition. But the ball F, which follows ball E with the same speed, meets ball E at rest after being stopped by ball d, and consequently it will give ball E its speed, which is then transferred to c and so on to ball b which will follow ball a. Now if the two balls E and F are in contact before the collision, and the other four also, the same effect should happen, because at the beginning of the collision ball E is separated a little from the ball F and ball d separates a little from ball c, as a consequence of the foregoing, and so on. By the same reasons above, only the two balls a and b move forward together, with the speed of both E and F, which will remain at rest, as well as the other two balls c and d. If there are three balls that collide, only the last three come forth, etc. We therefore see the causes of these effects, as has been proposed.

It is easy to demonstrate all of these effects using checkers of tric-trac[5], by sliding them in a straight line on a table. There will always emerge the same number of checkers that were thrown by hand against the others.

References

1. M.S. Mahoney, Mariotte, Edme
http://www.encyclopedia.com/topic/Edme_Mariotte.aspx

2. E.C. Watson, Edme Mariotte (c. 1620-1684), Am. J. Phys. 7, 230-232 (1939).

3. B. Davies, Edme Mariotte 1620-1684, Physics Education 9, 275- 278 (1974).

4. S. Hutzler, G. Delaney, D. Weaire and F. MacLeod, Rocking Newton's cradle, Am. J. Phys. 72, 1508-1515 (2004).

5. Tric-trac is an old French version of backgammon.