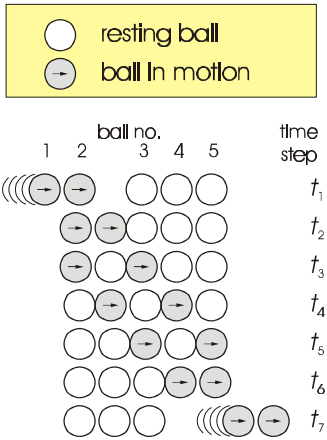
Question

How do the balls at one end of a Newton cradle know how many bumped onto the other end?

Answer

Only if the number of balls ejected equals the number of balls that have impacted, the conservation laws of energy and linear momentum are fulfilled.

Design of a Newton cradle A Newton cradle consists of several equal steel balls. The two thread suspensions along a straight line forces them to oscillate within a vertical plane.



Graphic description of a Newton cradle with two hitting balls

Physics The basic principle of the Newton cradle is the elastic collision of equal balls (= equal masses). A ball colliding with the center of a resting one transfers its total kinetic energy to it and remains still while the struck ball moves on at the speed of the colliding one. In reality the energy transfer is not complete because of the friction of the suspension and the friction of the air and because of the work of deformation in the balls.

Vivid description In our example the Newton cradle is made of five balls. Two of them have been moving and will bump on three resting balls. The figure illustrates how two hitting balls make two balls being ejected.
If we assume a tiny gap between the balls the problem can be reduced to the elastic collision of two equal balls. The figure shows the process in seven time steps. Ball 2 collides in step t_2 with the first resting ball and transfers in step t_3 its total energy to it. Immediately after that ball 1 transfers its energy to ball 2 which is resting meanwhile(step t_4). At the same time the energy of the ball which collided first has shifted one place to the right. In t_5 the energy states shift one more place to the right. In t_6 the first ball and finally in t_7 the second ball is ejected.
Problems with one, three, or four balls initially moving may be described equivalently.

Heinrich Hertz once calculated, that during a collision of two steel balls with a diameter of 5 cm and equal velocities toward each other of $v_1 = v_2 = 1$ cm/s they touch each other for 0,38 ms and that the touching area is .25 mm in diameter. Given we had steel balls with the size of the earth colliding at the same speeds the duration of the collision would equal 27 hours and the touching spot would have a diameter of 64 km.