Abstract:

1. The aim of the experiment is : to find the ratio R between the linear momentum before a collision between two balls and the linear momentum after so as to test the law of conservation of linear momentum which says that "the linear momentum of an isolated system is conserved ".
2. The method used is : measuring the horizontal distances after the balls fall and measuring the masses of them .
3. The main result is : $R = 1.06 \pm 0.02$

Theory:

First we use two balls with the same diameter so that the direction of the force that happens with the collision between the two balls would be straight so as to make the direction of the velocity after the collision for the pushed ball horizontal (by making the diameters equal we make the centers on a straight horizontal line) , so that we would make sure that there is no vertical velocity toward the ground would affect the motion of the ball .

We also make the heavier ball push the other ball so that the two balls would continue their way after collision horizontally to fall on sand wit different velocities . We don't choose the balls with the same weight because when the collision happens one of the balls will stop (the pushing ball) and the other will continue with the same speed of the pushing ball before it stops. We also don't choose the heavier ball to be the pushed one because the other ball would return back and push the heavier ball with a little force and make move softly .

We assume that the mass of the moving object = m , the velocity of it = v and the momentum of the object is (P) . Then :

$$P = mV$$

We consider an isolated system consisting of N objects , when the object no. i is moving with a velocity with mass of m_i , then the total momentum of the system is:

$$P = \sum_{i=1}^{N} m_i V_i$$

Assuming that the mass of the ball 1 is m_1, the mass of the ball 2 is m_2 , the speed of ball 1 before the collision is V_{1b}, the speed of ball 2 is zero ($V_{2b} = 0$) , the speed of ball 1 is V_{1a} and the speed of ball 2 is V_{2a} . We define the ratio R as :

$$R = \frac{P_a}{P_b}$$

$$P_a = m_1V_{1a} + m_2V_{2a} \quad \text{and} \quad P_b = m_1V_{1b} + m_2V_{2b} = m_1V_{1b}$$

Then by substitution: $R = \frac{m_1V_{1a} + m_2V_{2a}}{m_1V_{1b}}$

The ball falls in a parabolic trajectory inside the tray of sand .The vertical distance from the point of collision to the sand is $y = \frac{1}{2}gt^2$ where g is the acceleration of gravity and t is the time of flight for ball 1 which also equals the time of flight for the two balls after collision because both of them are falling freely under the acceleration of gravity and with the same initial velocity which equals zero .

Then we find $t = \sqrt{\frac{2y}{g}}$.

We assume that X_{1b} is the horizontal distance for ball 1 when it falls on the sand (before collision) , X_{1a} is the horizontal distance for ball 1 when it falls (after collision) , and X_{2a} is the horizontal distance for ball 2 when it falls (after collision) . As shown in figure 1 & figure 2 .

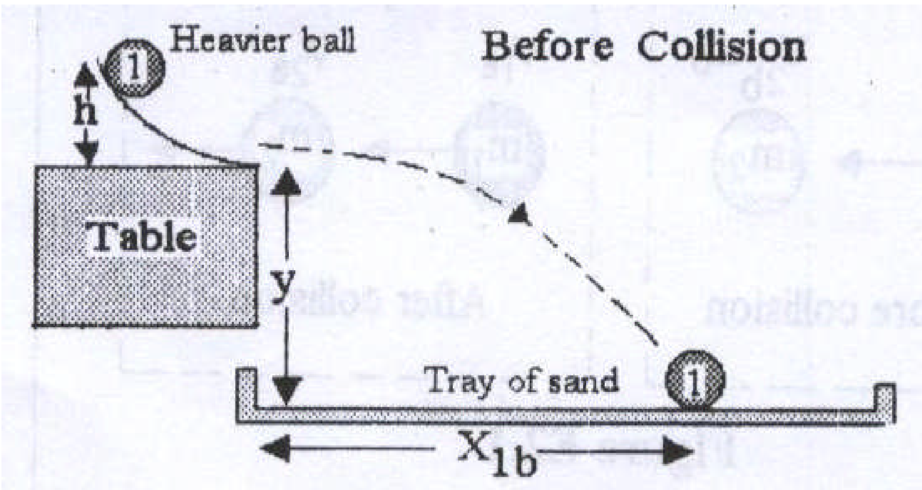

figure .1.

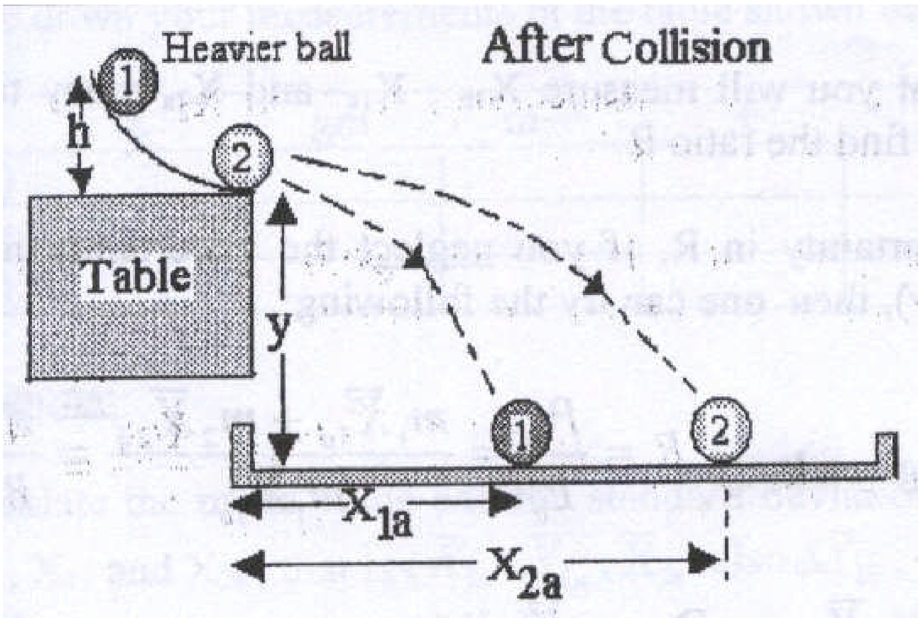

figure .2.

Then we find the horizontal speed of each ball to be :

$$V_{1b} = \frac{X_{1b}}{t} = \frac{X_{1b}}{\sqrt{2y/g}} \Rightarrow P_{1b} = \frac{m_1 X_{1b}}{\sqrt{2y/g}}$$

$$V_{1a} = \frac{X_{1a}}{t} = \frac{X_{1a}}{\sqrt{2y/g}} \Rightarrow P_{1a} = \frac{m_1 X_{1a}}{\sqrt{2y/g}}$$

$$V_{2a} = \frac{X_{2a}}{t} = \frac{X_{2a}}{\sqrt{2y/g}} \Rightarrow P_{2a} = \frac{m_2 X_{2a}}{\sqrt{2y/g}}$$

Substituting the equations in the equation of R we find that :

$$R = \frac{P_a}{P_B} = \frac{m_1 \overline{X}_{1a} + m_2 \overline{X}_{2a}}{m_1 \overline{X_{1b}}} = \frac{A}{B}$$

Where:

$$A = m_1 \overline{X}_{1a} + m_2 \overline{X}_{2a} \qquad B = m_1 \overline{X_{1b}}$$

$$\frac{\Delta R}{R} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$

where $\Delta A = m_1 \Delta \overline{X}_{1a} + \overline{X}_{1a} \Delta m_1 + m_2 \Delta \overline{X}_{2a} + \overline{X}_{2a} \Delta m_2$

and $\Delta B = m_1 \Delta \overline{X}_{1b} + \overline{X}_{1b} \Delta m_1$

Procedure:

First we fixed the curved track on a table and fixed the tray of sand certainly under the edge of the table . Then we chose two balls which have almost the same diameters to be used in the experiment. After that we rolled the ball no. 1 on the track and measured the distance $\overline{X}_{1b}$ on the sand , and then we made the surface of the sand flat as it was before the ball fell over it. We repeated this operation five times.

After that we stopped ball 2 on the edge of the track and then we rolled the ball no.1 toward ball 2 to make a collision between the two balls . Then we measured the distances $\overline{X}_{1a}$ and $\overline{X}_{2a}$ on the sand after each time we made the surface of the sand flat again. We repeated this five times.

Then we measured the masses of the two balls with the balance scale and repeated the measurement for each ball two times for checking.

The data we got is shown in the table.

Data:

$m_1 = 16.71$ g , $m_2 = 4.96$ g , $\Delta m_1 = 0.05$ g , $\Delta m_2 = 0.05$ g

No.						**Average**
$X_{1b}(cm)$	42.7	42.8	42.5	42.6	42.8	42.68
$X_{1a}(cm)$	25.8	25.4	26	26.7	26	25.98
$X_{2a}(cm)$	64.1	64.8	66	65.7	66	65.32

Calculations:

$$R = \frac{m_1 \overline{X}_{1a} + m_2 \overline{X}_{2a}}{m_1 \overline{X}_{1b}} = \frac{16.71 \times 25.98 + 4.96 \times 65.32}{16.71 \times 42.68} = \frac{758.113}{713.1828} = 1.062999 = 1.06$$

$$\Delta X_{1a} = \sigma_m = \frac{\sigma_s}{\sqrt{5}} = \frac{0.471168759}{2.236067978} = 0.210713075 = 0.2cm$$

$$\Delta X_{2a} = \sigma_m = \frac{\sigma_s}{\sqrt{5}} = \frac{0.84083292}{2.236067978} = 0.376031913 = 0.4cm$$

$$\Delta X_{1b} = \sigma_m = \frac{\sigma_s}{\sqrt{5}} = \frac{0.130384048}{2.236067978} = 0.058309518 = 0.06cm$$

$$A = m_1 \overline{X}_{1a} + m_2 \overline{X}_{2a} = 758.113 g.cm$$
$$B = m_1 \overline{X_{1b}} = 713.1828 g.cm$$

$$\Delta A = m_1 \Delta \overline{X}_{1a} + \overline{X}_{1a} \Delta m_1 + m_2 \Delta \overline{X}_{2a} + \overline{X}_{2a} \Delta m_2$$
$$= 16.71 \times 0.21071 + 25.98 \times 0.05 + 4.96 \times 0.376031 + 65.32 \times 0.05 = 9.951133772 g.cm$$

$$\Delta B = m_1 \Delta \overline{X}_{1b} + \overline{X}_{1b} \Delta m_1 = 16.71 \times 0.058309518 + 42.68 \times 0.05 = 3.108352046 g.cm$$

$$\frac{\Delta R}{R} = \frac{\Delta A}{A} + \frac{\Delta B}{B} = \frac{9.951133772}{758.113} + \frac{3.108352046}{713.1828} = 0.017484316$$
$$\Delta R = 0.017484316 \times 1.062999 = 0.018585811 = 0.02$$

$$R = 1.06 \pm 0.02$$

Results and Conclusion:

$$R = 1.06 \pm 0.02$$

I think that the result here is different a little from the real value (the result here ranges between 1.04 – 1.08 while the real value is 1.00) and this is related for some expected systematic errors during the experiment .

First if the lower of the track is not horizontal this would make the ball 1 before collision has a vertical with the horizontal one which we assumed that the vertical speed is zero and this would decrease our measurement for the horizontal distance on the sand. And like this would happen when the collision happens that the ball 1 would push the other ball with a force which is not horizontal so that it would affect on the angle of flying for each ball and make the horizontal distances measured on the sand less than the wanted one.

On the other hand the two balls we have chosen could be not the same diameters which we assumed at the beginning and this would affect that the force from the pushing ball won't be horizontal because the centers of the two balls won't be on a straight line as we assumed to make the velocities of the two balls horizontal and this would affect the measure of the horizontal distances just as when the track is not horizontal.

In another way the measurements taken with every instrument can't be very accurate because we always take the middle of the hole the ball would make when it falls on the sand and this estimation for the center of the hole can't be always very accurate because it depends on the sight which not accurate.