Experiment: 2D- Collision

Purpose

According to the result before and after the collision, we can verify the law of conservation of momentum.

Theory

When two balls collide, if there are no external forces and the resultant of forces is zero, the total momentum remains constant. In this experiment, we use the incident ball (the initial speed $\vec{v_1}$ and mass m_1) to collide with the target ball (mass m_2)

After the collision, $\vec{v_1}'$ presents the speed of the incident ball and its deviating angle is θ_1. $\vec{v_2}'$ presents the speed of the target , and its direction forms the angle θ_2 with the original incident direction. The total momentum before and after the collision are equal, and their relationship shown in Figure 1, which can be expressed as:

$$m_1\vec{v_1} = m_1\vec{v_1}' + m_2\vec{v_2}'$$

Assume the incident direction of the incident ball is the x-axis, so the component equations of the above equation in x and y directions respectively are:

$$m_1 v_1 = m_1 v_1' \cos\theta_1 + m_2 v_2' \cos\theta_2$$

$$0 = m_1 v_1 ' \sin \theta_1 - m_2 v_2 ' \sin \theta_2$$

The above equations represent the total momentum of the two balls in the x and y directions before and after the collision is conserved.

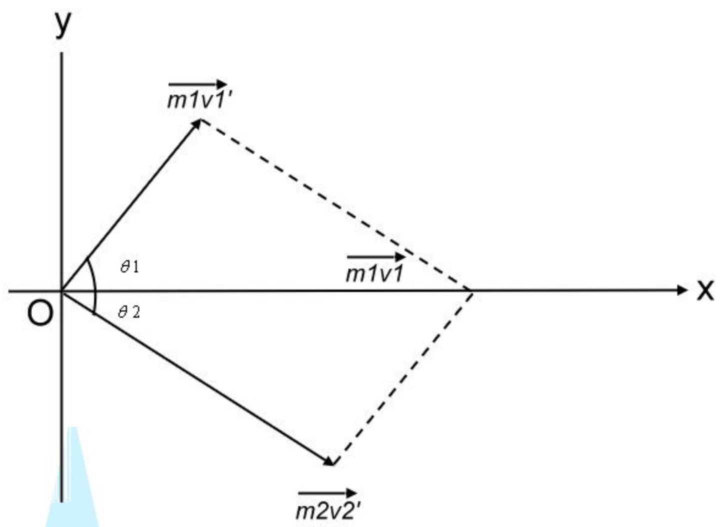

Figure 1

The conservation of total momentum before and after the collision

Instrument

NO	Accessory	Qty	NO	Accessory	Qty
1	Chute	1	2	Adjustable Base	1
3	Electromagnet	1	4	Support Frame	1
5	Plumb	1	6	Level	1
7	Steel ball	2	8	Glass Ball	1
9	C-shaped Clamp	1	10	Big Angle Scale	1
11	Carbon paper	Not included	12	2K Graph Paper	Not included
13	Small Angle Scale	1			

Detailed description of the instrument

①②Chute

· 7cm length antirust aluminum chute, fixed at 10mm thick acrylic board

·25 mm adjustable height

·size:205 × 120 × 160mm

③Electromagnet Ball Launcher

- L-shaped piece of metal length adjustment and the electromagnet launcher
- an electromagnet and an electromagnet power supply

④Support frame

· metal, adjustable collision angle from 0 to 40 degrees in vertical and oblique directions,

⑤Plumb

·metal, fixed position marking device

⑥Plastic multi-direction level

⑦Metal ball x2 (same mass)

⑧Non-metal ball x1

·a half of the mass but the volume is slightly larger than a ball of non-metallic ball

⑨ C-shaped clamp x2

·metal, tolerable thickness up to 60mm.

⑩Big angle scale

· from 0 to ± 20 degrees and 0 to 40 degrees dual-use (accuracy of 0.2 degrees)

· length 285mm, width 210mm

⑪Carbon paper x2

size: 48 x 70cm

⑫2K large graph paper x6.

⑬Small angle scale

· scale for measuring collision angle

Procedure

A. Instrument adjustments before the experiment

1. Fix the instrument using the c-shaped clamp on the table, and then put the level on the end of the chute. Adjust the screw to make the end horizontal. When the ball remains stationary on any point of the track, it means that the chute is adjusted horizontally and set for horizontal projectile motion.

2. Adjust the position of the electromagnet in the chute. Select the appropriate spot where incident ball falls, and fix the electromagnet to keep the ball in the same spot.

3. Mark a vertical projection point O using the plumb line and O_1 back to the platform direction 0.3cm where the ball falls as shown in Figure 2. i.e. $\overline{OO_3}$ and $\overline{OO_2}$ are 0.8 cm, take O_2 as the placement of on-the-same-line-collision and O_3 as the placement of the angle r 45 degrees after collision.

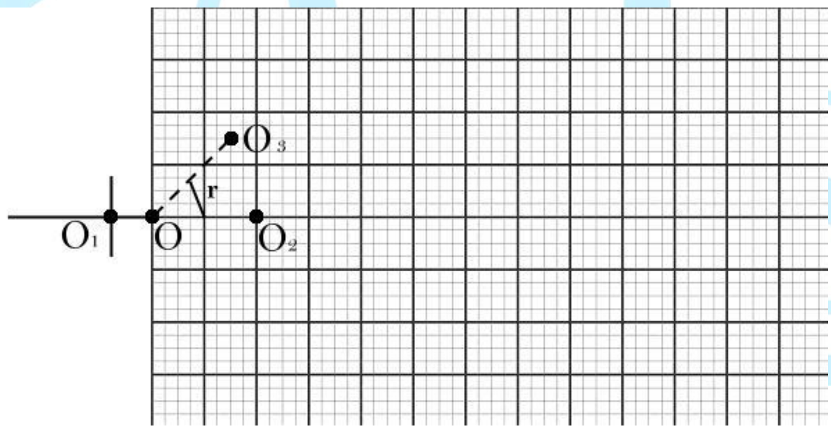

Figure 2

4. Adjust the height of the support frame, turn the support tube above and put the balls respectively at the throw end and the support tube. Make the center of the balls contour and fix the support frame height as shown in Figure 3.

5. Adjust the position of the support tube as shown in Figure 3, try throwing the balls by the following procedures. First, make the incident ball to do collision-free horizontal projectile motion (without a target ball) and use the carbon paper to

record the placement Q and draw $\overline{OQ}$ on the graph paper. Second, do the on-the-same-line collision again; the two placements of the balls should be nearby $\overline{OQ}$.

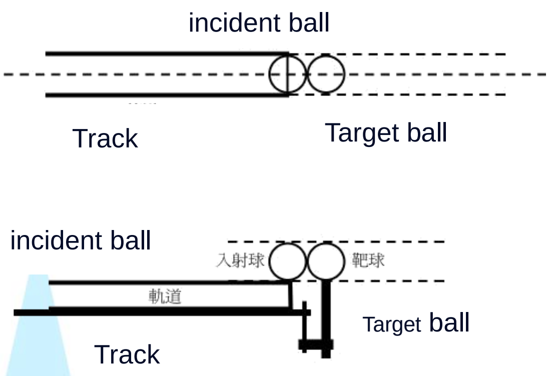

Figure 3

B. Measure the speed of the incident ball before the collision

1. Fix the experimental base on the table based on the A part above as shown in Figure 4. Put the graph paper on the ground and the carbon paper on the graph paper.

Note: must make $\overline{OQ}$ on the graph paper and overlap the falling trajectory as far as possible, in order to reduce experimental error.

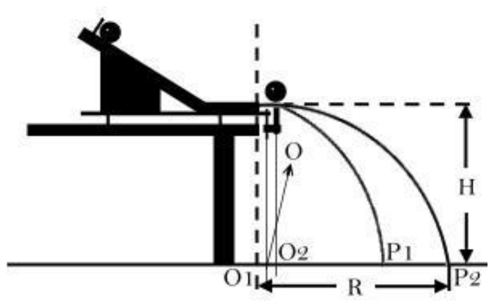

Figure 4

Measurement of the incident ball speed when falling

2. Mark the projection points O, O_1 and O_2, and measure the vertical height h of the

orbital end.

3. Choose an appropriate height as the fixed-point to release the incident ball, so that the ball falls along the chute, and finally falls on carbon paper. Mark the placement Q of the incident ball and record the length R of $\overline{O_1Q}$

4. Repeat the procedure 3 to four times.

C. Conservation of momentum before and after the collision

I. incident ball and target ball of different mass

5. Measure the mass of the incident ball (steel ball) m_1 and the target ball (glass ball) m_2.

6. Turn the support tube up and place the target ball. And measure the vertical height H from the bottom of the target ball to the ground.

7. Adjust the position of the target ball on the support tube, so that the center of the balls on the same level as shown in Figure 3. Then release the incident ball to collide the two balls so they will fall on the graph paper. Mark the placements P_1 and P_2 of the two balls, record the length R_1 and R_2 of $\overline{O_1P_1}$ and $\overline{O_2P_2}$, and measure the angles θ_1 and θ_2 between $\overline{O_1P_1}$ and $\overline{O_2P_2}$ and the incident direction.

8. Repeat the procedure 7 four times.

9. Adjust the position of the target ball on the support tube, so that the center of the balls on the same level as shown in Figure 3. Then release the incident ball to collide the two balls so they will fall on the graph paper. Mark the placements P_3 and P_4 of the two balls, record the length R_3 and R_4 of $\overline{O_1P_3}$ and $\overline{O_3P_4}$, and measure the angles θ_3 and θ_4 between $\overline{O_1P_3}$ and $\overline{O_3P_4}$ and the incident direction.

10. Repeat the procedure 9 four times.

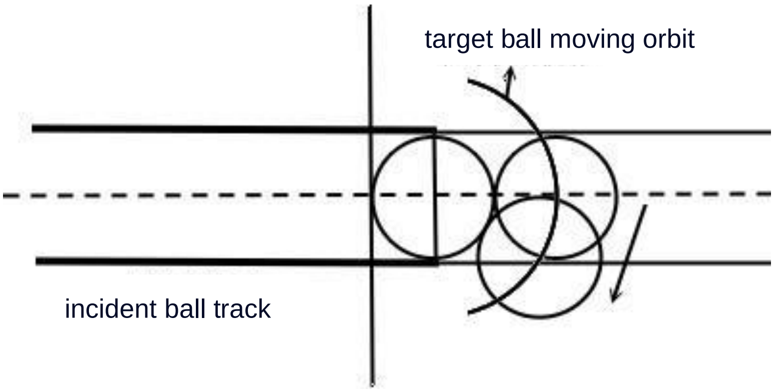

Figure 5

<u>II. incident ball and target ball of the same mass</u>

11. Take two steel balls of the same mass as the incident ball and the target ball. Turn the support tube up and place the target ball. And measure the vertical height H_1 from the bottom of the target ball to the ground.

12. Adjust the position of the target ball on the support tube, so that the center of the balls on the same level as shown in Figure 5. Then release the incident ball to collide the two balls so they will fall on the graph paper. Mark the placements P_5 and P_6 of the two balls, record the length R_5 and R_6 of $\overline{O_1P_5}$ and $\overline{O_3P_4}$, and measure the angles θ_5 and θ_6 between $\overline{O_1P_3}$ and $\overline{O_3P_6}$ and the incident direction.

13. Repeat the procedure 12 four times.

Note

1. The chute should be carefully stored, non-collision damage, so as to avoid the experimental error.

2. If the chute isn't smooth, it may cause a great error due to friction.

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