PROJECT 7

AIM

To study the collision of two balls in two-dimensions.

APPARATUS AND MATERIAL REQUIRED

Apparatus for collision in two dimensions, metre scale, tracing paper, carbon paper, G-clamp, a screw, cellotape, protractor, two identical steel spheres or marble spheres and a plumbline.

DESCRIPTION OF APPARATUS

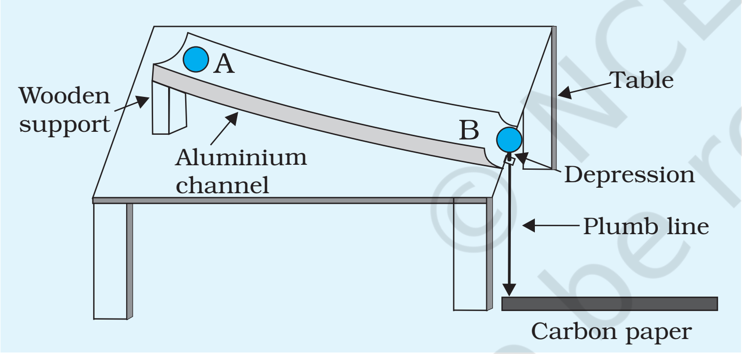

Fig. P 7.1: *Setup to study the collision of two balls in two-dimensions*

A scale or ruler with a groove (or an aluminium channel) which is bent to act as a ramp so that a steel ball can be rolled from the top. At the lower end of the ruler a set screw is fixed that has a depression on its top. This is the resting place for the target steel ball. The ruler rests on a metal base which can be clamped at the edge of a laboratory table. From the set screw, a plumbline is suspended as shown in Fig. P 7.1.

PRINCIPLE

When two steel spheres of mass m and m′ moving with velocities $\boldsymbol{u}$ and $\boldsymbol{u}'$ respectively collide, their velocities change after collision. If their velocities after collision are $\boldsymbol{v}$ and $\boldsymbol{v}'$ respectively, then according to the law of conservation of momentum

$$m\boldsymbol{u} + m\boldsymbol{u}' = m\boldsymbol{v} + m\boldsymbol{v}'$$

In this Activity, we study collision of two balls in two-dimensions using the apparatus described above and verify the law of conservation of momentum in two-dimensions. We allow one steel ball to roll down the ramp and collide with a target ball (at rest) placed at the lower end of the ramp. For simplicity, we take two identical balls.

After collision the two balls moving in different directions fall down and strike the ground. The horizontal velocity of each sphere is proportional to the horizontal distance travelled by each sphere (Why this should be so?). The horizontal distance is the distance from point on the floor just below the initial position of the stationary ball to the point where it lands. This same horizontal distance can also be used to represent the magnitude of the momentum of each ball as they have the same mass.

PROCEDURE

1. Arrange the apparatus as shown in Fig. P 7.1. Adjust the set screw so that the depression in it is directly in front of the groove and about one radius of the steel ball away from the groove end. Roll a steel ball down the ramp and adjust the set screw by moving upward/downward so that the ball just clears it as it falls freely. Place the target ball on the depression in the screw. Suspend the plumb line with it.
2. Next adjust the position of the set screw so that the bullet ball will collide with the target ball at an angle. Mark the incident and target balls as 1 and 2. Ensure that the two balls are exactly at the same height from the floor at the time of collision.
3. Spread on the floor a large sheet of tracing paper on a similar sized carbon paper. The steel balls would be falling on this combination to make their imprints. In case large sheets of carbon paper or plain paper are not available tape together their pieces (A-4 size) to make a large sheet.
4. Put the carbon paper on the floor, with its inked side facing up. Place the tracing paper directly over it. Place the sheets such that the centre of one end of the paper lies just below the plumb line.
5. Without placing a target ball on the set screw, roll the ball marked 1. Mark the point on the tracing paper where the ball lands (P_0). Repeat it several times and mark the cluster P_{01}, P_{02}, P_{03}, etc. ... Find the centre of the cluster and mark it P_0.
6. Using identical steel ball (2) to act as a target ball, try a few collisions. Ensuring that the incident ball (1) is always released from the same height. Circle and label the clusters of points where the incident ball and the target ball hit the paper.

   (You can find the centre of cluster points, by drawing a quadrilateral and intersecting diagonals to find the location of mean point.)

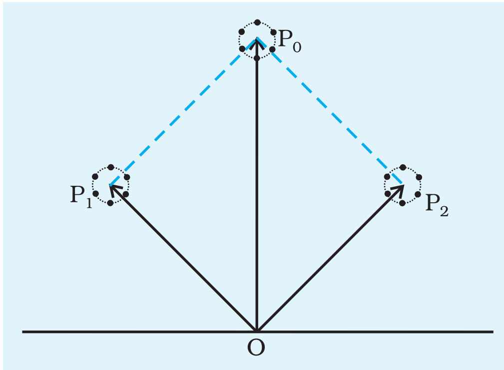

Fig. P 7.2: *To find location of mean print*

7. Mark point *'O'* on the paper where the plumb line touches the paper. Draw vectors from the point O to the mean point P_0, P_1 and P_2.

8. (a) Add the two vectors OP_1 and OP_2 representing the momentum of the incident ball and target ball to determine the total momentum *P* after the collision (Fig. P7.2).

   (b) Relate the total momentum *P* after the collision with the initial momentum of the incident ball represented by vector OP_0 and the target ball.

RESULT

The total momentum of the two ball after collision is ... g cms^{-1} which is almost equal to the initial momentum of the incident ball.

PRECAUTIONS

1. Adjust the set screw and ensure that the two balls are exactly at the same height from the floor at the time of collision.
2. In each trial, the incident ball should be rolled down from the same height.

SOURCES OF ERROR

Friction between the ball and surface may introduce an error.

SELF ASSESSMENT

1. For each trial, measure the angle between the two final momentum vectors. Can you make any generalisation?
2. Suppose the target ball is replaced by a glass marble of same size and we carry out the experiment using the same incident ball. In

this case, the horizontal distances, would represent velocity vectors? Do they still represent momentum vectors? How will you draw momentum vectors in this case and verify the law of conservation of momentum?

3. What happens to the momentum components corresponding to OP_1 and OP_2 in Fig. P7.2 in the direction perpendicular to OP_0?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

This experiment can also be used to verify the law of conservation of momentum quantitatively, the momentum of a ball can be calculated knowing its mass and velocity. Measure the mass of each ball with a balance. The horizontal velocity is equal to the horizontal distance travelled divided by the time taken. Note that this time is equal to the time taken by the ball to hit the floor. This time can be determined by measuring the distance (d) from the top of the set screw to the floor and using the equation $d = (gt^2)/2$. Further, note that t will be the same for all calculations.

Calculate the original momentum of the incident ball and final momenta of the incident and target balls for the case with balls of (1) equal mass and (2) unequal mass. Find the resultant of the two final momenta in each case and compare it with the initial momentum.

ALTERNATE METHOD FOR MAKING CHANNEL

Take plastic pipe having internal diameter slightly more than the diameter of the balls.

Cut the pipe lengthwise into two equal parts (two halves). Bend slightly one part of the cut pipe by gently warming it and fix it on a table top as shown in the figure below.

Make a small depression near end B of the pipe with the help of a heated thick nail/rod for resting the target ball.