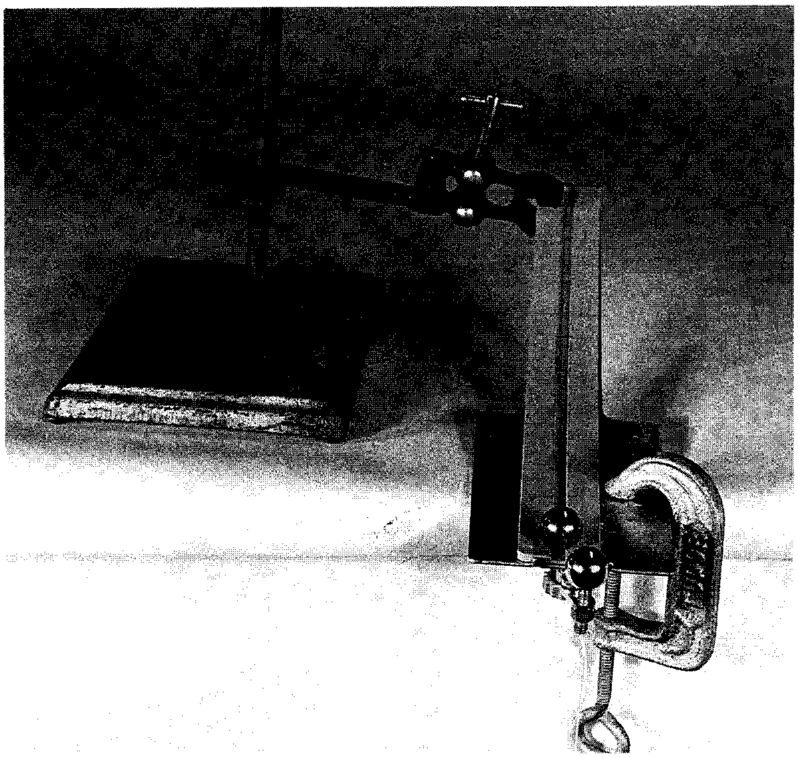
# COLLISIONS IN TWO DIMENSIONS KIT



This kit enables students to investigate collisions in one and two dimensions thus exploring the conservation of momentum and energy.

There are a number of variations of this kit available, but the essentials are the same. The equipment consists of a curved grooved track, along which a steel ball is allowed to roll.

At the end of the track there is an arm to hold a second ball in a stationary position. This arm can be adjusted to position the ball for a head-on collision or one at a glancing angle. Both balls are launched into a trajectory with the point of impact on the floor being recorded by a piece of carbon on plain paper.

## SETTING UP AND USING THE COLLISIONS IN TWO DIMENSIONS KIT

**X** **Extra equipment for the suggested learning experiences includes:**

- carbon paper
- large sheets of white paper
- plumb bob and string
- meter rule
- g-clamp
- retort stand, bosshead and clamp
- vernier callipers
- balance to measure the mass of the balls
- protractor
- masking tape
- steel balls (not marbles, as there is a 20% variation in mass)

**S** **Setting up the Collisions in Two Dimensions Kit**

- Clamp the curved track to the edge of the bench with a G-clamp so that the lower end extends out from the edge of the bench.

- Fix the upper end of the track in a clamp attached to a retort stand. The clamp should be close to the bench top.
- Hang a plumb bob on the end of a long thread from the set-screw on the adjustable arm at the end of the track, directly below the target ball. For accurate measurement the plumb bob should be poised just above the floor.
- Tape some plain paper to the floor, to cover the area in which the balls are expected to hit. NOTE: To estimate the size of this area, let the ball roll freely down the track and note its position as it hits the floor. Repeat, placing another ball on the adjustable arm and once again note the position at impact with the floor.
- Measure the mass of each of the steel balls. Select two with the same mass and one with a much lighter mass.
- Measure and record the diameter of the steel balls using vernier callipers.
- Set the adjustable arm so that there is a distance of 1.5 times the diameter of the target ball between the centre of the target ball and the end of the track (*see figure 1*).

  NOTE: For some sets of equipment this will require the use of steel balls with a maximum diameter of 13mm.
- Move this bracket to make an angle of approximately 45° with the path of the rolling ball. Fasten the bracket tightly in position.
- Loosen the lock-nut on the adjustable arm and adjust the height of the set-screw on which the target ball sits so that the rolling ball just skims across the top of it. Tighten the lock-nut in place.
- Place a target ball on the adjustable arm at the end of the track.
- Fasten some carbon paper face down on top of the plain paper.

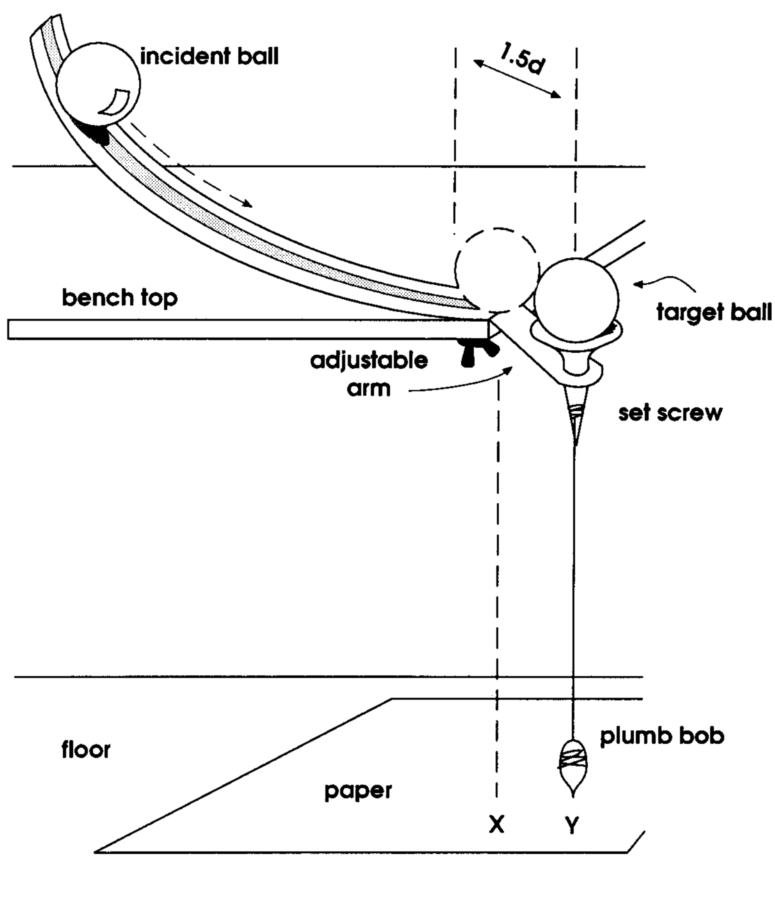



*figure 1*

## HANDY HINT

- To ensure that there is no confusion, mark each point of impact immediately after the event by lifting the carbon and marking the point with a circle and number to indicate the order of events.

# SUGGESTED LEARNING EXPERIENCES

The learning experiences require a similar procedure and analysis which is outlined below.

## Procedure

- Mark the position of the plumb bob clearly on the paper directly below the centre of the target ball (*'Y' in figure 1)*
- Measure accurately and record on the paper the point directly below the centre of the rolling ball at the time of impact (*'X' in figure 1*).
- Experiment to find a suitable position from which to release the rolling ball (approx. 25 cm). Mark this position clearly on the ruler and always release from the same point being careful not to push the ball so that the acceleration is only due to gravity.
- Release the ball from this point several times and mark the spot clearly on the paper where it hits the floor.
- Set up another steel ball on the adjustable arm and proceed with the specific collision required.
- Take an average of at least five readings when collecting results.
- Connect the initial and final points of impact for each ball on the paper with straight lines and measure their length.

## Analysis

To alleviate confusion about the quantities actually being measured, students should be made aware of the following:
Since the balls are released in a trajectory motion, their horizontal velocity will be constant, while they accelerate vertically to the floor under the force of gravity (assuming air resistance is minimal). As the time taken to reach the floor is the same for each ball under gravity, then the displacement of each ball is directly proportional to its horizontal velocity. (**d=v.t**) Hence measuring the displacements of the steel balls provides a *proportionate* measure of their velocities (not the actual velocities) in the horizontal plane. If the masses of the balls are the same, the displacement vectors can be compared directly to demonstrate conservation of momentum.

## TOPIC - Collisions

1. **Verify the conservation of momentum in a 2-dimensional collision** using identical balls set at an angle of approximately 45°. Draw the displacement vectors of both balls after the collision on the paper, adding them vectorially, head to tail. Compare this with the displacement vector of the incident ball when there is no target ball to hit. Discuss sources of error.

   Repeat the collision using different angles.

   Repeat the collision using a lighter ball as the target ball. (In this case momentum vectors will have to be drawn taking into account the difference in mass.)

2. **Investigate the conservation of kinetic energy using similar conditions for a 2-dimensional collision as in part 1.** To compare kinetic energy, square the magnitudes of the displacements and simply add them as kinetic energy is not a vector quantity.

3. **Verify the conservation of momentum for a head-on 1-dimensional collision**, being very careful to align exactly the centres of the colliding balls.
   Repeat the collision using balls of different masses.

4. **Investigate the conservation of kinetic energy in a 1-dimensional collision.**
   *For more information, see the PSSC manual p51, or Essential Physics, page 76.*