Core practical 10: Use ICT to analyse collisions between small spheres

Objectives

- To investigate the conservation of momentum in two dimensions
- To determine whether a collision is elastic

Safety

- The masses and energies in this practical are low.
- Normal laboratory practice is expected.

Specification links

- Practical techniques 1, 2, 3, 5, 11
- CPAC 2a, 2d, 5a

Procedure

1. Measure the mass and the diameter of the spheres.
2. Start a collision between a moving sphere and a stationary one. Set the table or drawing board at a slight angle and roll the sphere along the upper edge of a rule. The collision occurs along the rule. This enables you to familiarise yourself with the equipment and allows for calibration.
3. After sufficient rehearsal, set up the digital camera to record the collisions. Lay the surface out horizontally and roll one sphere into a second stationary one again. This time the collision is unlikely to remain in one dimension, and there will be three tracks to record.
4. Repeat, varying the line of approach so that a variety of collision angles are employed. It may help to mark the graph paper or dressmaking paper where the stationary sphere is placed to allow for small variations in approach. With practice, you will be able to use spheres of different diameters.
5. Use *Tracker* to analyse the video clips. Download the video file from the camera to the computer that runs *Tracker* and then load the clip into the program.
6. Use the 'velocity overlay' feature so that the software can analyse velocities. You will need to multiply by the mass if you are to analyse the momentum.
7. You will need to keep a record of your work. This can either be on a digital file or by drawing the diagrams on paper and annotating them clearly and correctly.

Notes on procedure

- This is an investigation that students can take ownership of. The software used is a small yet powerful free program called *Tracker.*
- CPAC 2a and 2d are determined by variety and success in students' diagrams and 5a is evidenced by their use of the software.

Answers to questions

1. Estimation of uncertainties can be based on variations in repeated readings where possible, otherwise the resolution of the measurements can be used.
2. Responses should be recorded in students' notebooks and could include any aspect of the work.

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All the maths you need

- Recognise and make use of appropriate units in calculations.
- Use calculators to handle sin *x*, cos *x*, tan *x* when *x* is expressed in degrees or radians.
- Use an appropriate number of significant figures.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.
- Use angles in regular 2D and 3D structures.
- Use Pythagoras' theorem, and the angle sum of a triangle.
- Use sin, cos and tan in physical problems.

Equipment

- small spheres (it is helpful to have spheres of two different diameters)
- digital camera able to record video
- computer with *Tracker* installed
- ruler
- micrometer or callipers
- means of controlling collision between two spheres
- support for camera vertically above the collision
- mass balance
- graph paper or dressmaking paper

Procedure

1. Measure the mass and the diameter of the spheres.
2. Start a collision between a moving sphere and a stationary one. Set the table or drawing board at a slight angle and roll the sphere along the upper edge of a rule. The collision occurs along the rule. This enables you to familiarise yourself with the equipment and allows for calibration.
3. After sufficient rehearsal, set up the digital camera to record the collisions. Lay the surface out horizontally and roll one sphere into a second stationary one again. This time the collision is unlikely to remain in one dimension, and there will be three tracks to record.
4. Repeat, varying the line of approach so that a variety of collision angles are employed. It may help to mark the graph paper or dressmaking paper where the stationary sphere is placed to allow for small variations in approach. With practice, you will be able to use spheres of different diameters.
5. Use *Tracker* to analyse the video clips. Download the video file from the camera to the computer that runs *Tracker*, and then load the clip into the program.
6. Use the 'velocity overlay' feature so that the software can analyse velocities. You will need to multiply by the mass if you are to analyse the momentum.

7. You will need to keep a record of your work. This can either be on a digital file or by drawing the diagrams on paper and annotating them clearly and correctly.

Analysis of results

1. It is probably easiest to lay the *x*-axis along the path of the incoming sphere, then the components in the *x*-direction and the *y*-direction are the maximum and zero respectively.
2. You will need to measure velocities as vectors, having magnitude and direction, so measuring angles is extremely important.
3. You should analyse the tracks to see if momentum is conserved along the line of the approach and perpendicular to that line.
4. Construct a momentum vector triangle and use it to see if it closes (meaning momentum is conserved). You can also use the vector triangle to consider energy. You should find that when kinetic energy is conserved there is a right angle between the two spheres after collision (so long as the target sphere was stationary and the spheres have the same mass).

Learning tip

- You will need to be able to use the sine and cosine functions to calculate components.

Questions

1. Estimate the uncertainties in your calculated values.
2. Describe any difficulties you encountered in measuring the data.

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Equipment per student/group	**Notes on equipment**
small spheres (it is helpful to have spheres of two different diameters)	Ball bearings are visible on camera, but ensure they are not too large. 9.5 mm in diameter is a good size as it can be easily seen. It is difficult to see the edge of a glass marble, but they can also be used.
digital camera able to record video	A phone camera may be suitable, but it must have a means to transfer the video to the computer.
computer with *Tracker* installed	*Tracker* is available as a free download from *Open Source Physics* at http://www.opensourcephysics.org/items/detail.cfm?ID=7365. The program is compatible with Windows or Mac.
ruler	
micrometer or callipers	To measure the diameter of the spheres
means of controlling collision between two spheres	One sphere can be stationary, and the travelling one can be launched from a curtain track or similar.
support for camera vertically above the collision	The field of view must be sufficient to show tracks before and after collision. It helps if the spheres roll and collide on graph paper or dressmaking paper. This can be achieved by using a drawing board or simply fixing the paper to a bench with sticky tape. It is also helpful if the surface can be set at a slight angle to the horizontal to compensate for friction.
mass balance	To measure the mass of the spheres
graph or dressmaking paper	
Notes	