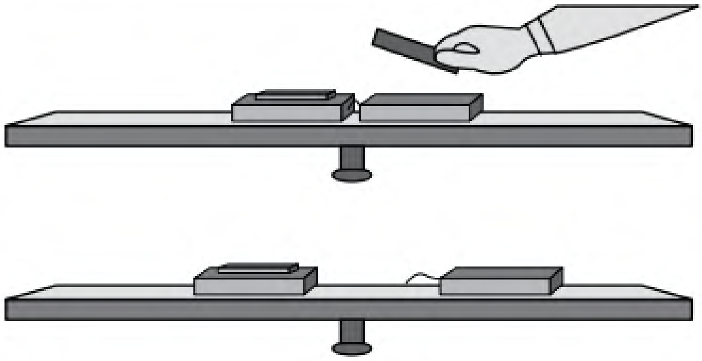
PRACTICAL INVESTIGATION 45 MARKS

Principle of conservation of linear momentum: The total linear momentum of an isolated system remains constant (is conserved).



Aim: To verify the principle of conservation of linear momentum.

Investigative question:

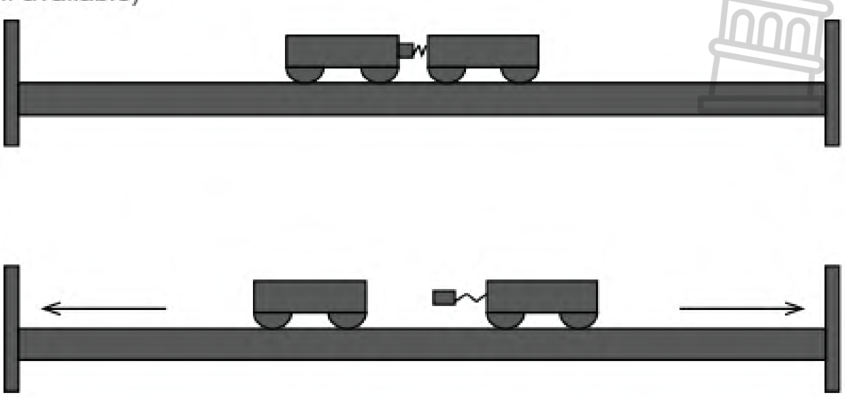
1. Does the principle of conservation of linear momentum hold true even for an inelastic explosion of two objects?
2. Technical note:
3. Because the levelling of the horizontal track is essential in this experiment, the learners will require help and supervision to ensure that their track is correctly adjusted.

Technical note:

Because the levelling of the horizontal track is essential in this experiment, the learners will require help and supervision to ensure that their track is correctly adjusted.

Apparatus

Smooth horizontal level track (almost frictionless)
2 trolleys which can couple and decouple with a spring mechanism
2 sets of masses for the trolleys
2 stoppers (one for each end of the track)
Measuring tape
Ruler (or stick) to use when decoupling the two trolleys
Spirit level (if available)



Method

A. Levelling the horizontal track

The track must be perfectly level in order to obtain reliable results.

Using the spirit level:

1. To level the track, place the spirit level lengthwise in the middle of the track. Adjust the supports at either end of the track until the air bubble in the spirit level rests exactly in the centre.
2. Keep the spirit level lengthwise on the track and move the it to other positions along the length of the track. Adjust the supports at either end of the track whenever necessary.
3. Turn the spirit level at right angles to the length of the track. Check that the air bubble in the spirit level rests exactly in the centre. Adjust the supports at either end of the track to ensure that the track is also level in the horizontal direction.

Using the motion of a trolley:

When the track is perfectly level a trolley will remain stationary on the track.

1. Place a trolley in the middle of the track.
2. Release it and watch which way it moves.
3. If it moves to the left, raise the support on the left a little, and repeat step 1 and 2.
   If it moves to the right, raise the support on the right a little, and repeat step 1 and 2.
4. If the trolley remains stationary, move the trolley to other positions on the track to check that it remains stationary when it is released. If it moves go back to step 1 to 3, until the trolley remains stationary on the track in any position.

Investigating the principle of conservation of momentum.

The theory upon which this method is based.

When two objects in an isolated system are at rest, and they are forced apart during an explosion, their linear momentum remains constant.

$m_1v_{i1} + m_2v_{i2} = m_1v_{f1} + m_2v_{f2}$ (by the law of conservation of linear momentum)

The initial linear momentum of the two objects at rest is zero (because v_{i2} and v_{i2} are both equal to zero).

$0 = m_1v_{f1} + m_2v_{f2}$

$m_1v_{f1} = - m_2v_{f2}$

If both trolleys have the same mass ($m_1 = m_2$) since their momentum is the same but in opposite directions, the trolleys have the same speed and they move in opposite directions.

$v_{f1} = -v_{f2}$

Since both are travelling at the same speed, they cover the same distance in the same amount of time. If the trolleys are released from the midpoint of the track, they will crash into the stoppers at the ends of the track at exactly the same moment. The noise of these collisions will be synchronised into one impact noise.

When this happens we know that $v_{f1} = -v_{f2}$ therefore $m_1v_{f1} = -m_2v_{f2}$ as is predicted by the principle of conservation of linear momentum.

So, we are going to position the trolleys on the track so that when they explode away from each other, they both collide with the stoppers at each end at precisely the same moment. We will know this has happened because we will hear only one simultaneous "bang" from both collisions.

To check that the principle applies for any variation of mass of the trolleys we will add various mass pieces to the trolleys, and move them on the track so that their collision with the stoppers coincides exactly. To check that the principle of conservation of linear momentum applies we then need to take readings of the mass of each trolley and the distance that it has moved from the release point to the stopper.

Using this information, we can calculate whether the law of conservation of momentum applies in each experiment.

Carry out the experiment using these principles, then INDIVIDUALLY write down the method which you used while doing the experiment. Record the results of your experiments in the table of results which follows.

Method: (6)

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Results:

1. Explain the reasoning that allows us to accept that if $m_1\Delta x_1 = m_2\Delta x_2$ (where Δx_1 and Δx_2 are the distance of the respective trolleys from their stoppers) then in this particular experiment, then we have proved that $m_1v_{f1} = -m_2v_{f2}$. (4)

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2. Complete the following in the table of results in the following way:
   - Write a title for the table. (1)
   - Fill in the SI units. (2)
   - Watch the video and record the appropriate values. (8)
   - Calculate the values for columns 3 and 6. (8)
   - Fill in the column labelled inference by deciding whether the law of conservation of momentum holds true in this experiment or not. Show your reasoning very briefly. (4)

Table of results:

Trolley (Red)			Trolley (Blue)			Inference
m_{red}	Δx_{red}	$m_{red}\Delta x_{red}$	m_{blue}	Δx_{blue}	$m_{red}\Delta x_{blue}$	

3. Independent variable:

   Dependent variable:

   Control variable(s): (4)

4. Discuss two factors which could negatively influence the outcome of this investigation, and briefly explain how they could affect it, and how their influence could perhaps be minimised. (6)

Conclusion: (2)

Principle of Conservation of Linear Momentum

Method: (6)

1. *Measure and record the total mass of each trolley and its mass pieces.✓*
2. *Place the trolleys on the track with the spring-loaded release placed between them. ✓*
3. *Strike the spring-loaded release switch to explode the trolleys apart. ✓*
4. *Adjust the distance of the two trolleys from their respective stoppers until they both strike their respective stoppers simultaneously. ✓*
5. *Measure and record the start distance✓ of the front ✓of each trolley from their respective stoppers.*
6. *Repeat step 1 to step 5 until four different combinations of masses have been recorded.*

Results:

1. Explain the reasoning that allows us to accept that if $m_1\Delta x_1 = m_2\Delta x_2$ (where Δx_1 and Δx_2 are the distance of the respective trolleys from their stoppers) then in this particular experiment, then we have proved that $m_1v_{f1} = -m_2v_{f2}$. (4)

   Both trolleys hit the stopper at the same time Δt.✓

   The velocity of trolley 1 = $v_{f1} = \frac{\Delta x_1}{\Delta_t}$ *therefore its momentum* $p_{f1} = m\frac{\Delta x_1}{\Delta_t}$ *left.✓*

   The velocity of trolley 2 = $v_{f2} = \frac{\Delta x_2}{\Delta_t}$ *therefore its momentum* $p_{f1} = m\frac{\Delta x_2}{\Delta_t}$ *right.✓*

   They are travelling in the opposite directions.

   If the magnitude of $m\frac{\Delta x_1}{\Delta_t}$ *is equal to the magnitude of* $m\frac{\Delta x_2}{\Delta_t}$ *then* $m_1v_{f1} = -m_2v_{f2}$.✓

   But Δ is the same in both instances, therefore $m_1\Delta x_1 = m_2\Delta x_2$ *proves that the law holds true.*

2. Complete the following in the table of results in the following way:

Table of results:

Comparing (the magnitude of) the momentum of trolley 1 with that of trolley 2 after an explosion.✓

Trolley (Red)			Trolley (Blue)			Inference
m_{red} (kg)	Δx_{red} (m)	$m_{red}\Delta x_{red}$ (kg.m)	m_{blue} (kg)	Δx_{blue} (m)	$m_{red}\Delta x_{blue}$ (kg.m)	
0,250	0,63✓	0,1575✓	0,250	0,63✓	0,1575✓	$m_{red}\Delta x_{red} = -m_{blue}\Delta x_{blue}$ therefore $\Sigma p_{initial} = \Sigma p_{final}$✓
0,500	0,63✓	0,3150✓	0,500	0,63✓	0,3150✓	$m_{red}\Delta x_{red} = -m_{blue}\Delta x_{blue}$ therefore $\Sigma p_{initial} = \Sigma p_{final}$✓
0,500	0,42✓	0,21✓	0,250	0,84✓	0,21✓	$m_{red}\Delta x_{red} = -m_{blue}\Delta x_{blue}$ therefore $\Sigma p_{initial} = \Sigma p_{final}$✓
0,750	0,31✓	0,2325✓	0,250	0,93✓	0,2325✓	$m_{red}\Delta x_{red} = -m_{blue}\Delta x_{blue}$ therefore $\Sigma p_{initial} = \Sigma p_{final}$✓

Principle of Conservation of Linear Momentum

3. Independent variable: *masses of trolleys 1 and 2✓*
   Dependent variable: *velocities (speeds, or distances) of trolleys 1 and 2✓*
   Control variable(s): *time of collision✓*
   (level horizontal or same) track✓ (4)

4. Discuss two factors which could negatively influence the outcome of this investigation, and briefly explain how they could affect it, and how their influence could perhaps be minimised. (6)
   4.1 *Releasing the trolleys in the explosion ✓*
   Hitting the spring release exactly perpendicularly is very difficult. ✓ If the spring release is hit giving one or other or both trolleys a slight impetus (component of horizontal force) ✓ then the outcome is affected negatively. The trolley with the slight extra force✓ will travel a little faster to the stopper than it would have done without this extra force✓. The times will be inaccurate so the distances will be inaccurate ✓ and the linear momentum of the system will appear to not be conserved.

Conclusion: (2)

The total linear momentum of an isolated system✓ remains constant.✓