Raksha Dave
B.SC(Physics)
ATMIYA University Rajkot Gujrat

APPS ON PHYSICS

Elastic and Inelastic Collision

Reference: Simulation is available on Apps on Physics
Interface: Apps on Physics >> Mechanics >> Elastic and Inelastic Collision

Abstract:

Collisions are fundamental interactions in physics where two or more bodies exert force on each other. Collisions are of two types. Elastic collisions are those in which momentum and kinetic energy both are conserved, and Inelastic collisions, in which only momentum is conserved.

The experiment on collisions is provided in **Apps on physics > Mechanics > Elastic & Inelastic collision.**
This simulation contains all relevant parameters.

The nature of a collision, whether it is elastic or inelastic is determined by the coefficient of restitution (e).

$$e = \frac{|v_2' - v_1'|}{|v_2 - v_1|}$$

Where:

- v_1 and v_2 are the velocities of the two objects before the collision.
- v_1' and v_2' are the velocities of the two objects after the collision.

- **Elastic Collision**: If e=1, the collision is **elastic**, meaning no kinetic energy is lost.
- **Inelastic Collision**: If 0<e<1, the collision is **inelastic**, meaning some kinetic energy is lost but the objects still separate, momentum is conserved.
- **Perfectly Inelastic Collision**: If e=0, the collision is **perfectly inelastic**, meaning the objects stick together and maximum kinetic energy is lost.

Key words: conservation of energy, conservation of momentum, coefficient of restitution.

Aim of the Experiment:

To study and analyze elastic and inelastic collisions, verify the conservation of momentum in both cases, and examine the conservation or transformation of kinetic energy during the collisions.

Introduction:

Collisions are fundamental interactions in mechanics that follow the principles of conservation of momentum and energy. They are broadly classified into two types:

1) **Elastic collisions:**

   In these collisions, both momentum and kinetic energy are conserved. The colliding bodies retain their original forms without generating heat or undergoing deformation. Such collisions are typically observed in systems like ideal gas molecules or perfectly rigid bodies.

2) **Inelastic collision:**

Here, momentum is conserved, but a portion of the kinetic energy is converted into other forms such as heat, sound, or internal energy. In a perfectly inelastic collision, the colliding objects stick together after impact, moving as a single entity.

Formula used:

If two objects A and B collide with each other then the formulae are,

FOR ELASTIC COLLISION:

Coefficient of restitution:

$$e = \frac{v_b' - v_a'}{v_a - v_b}$$

Where:

- e = coefficient of restitution
- v_a = initial velocity of object A (before collision)
- v_b = initial velocity of object B (before collision)
- v_a' = final velocity of object A (after collision)
- v_b' = final velocity of object B (after collision)

Velocity of object A and B after collision:

$$v_a' = \frac{(m_a - m_b)v_a + 2m_b v_b}{m_a + m_b}$$

$$v_b' = \frac{2m_a v_a + (m_b - m_a)v_b}{m_a + m_b}$$

- v_a': Final velocity of object A after the collision.
- v_b': Final velocity of object B after the collision.
- m_a: Mass of object A.
- m_b: Mass of object B.
- v_a: Initial velocity of object A before the collision.
- v_b: Initial velocity of object B before the collision.

FOR INELASTIC COLLISION:

Coefficient of restitution:

$$e = \frac{v_b' - v_a'}{v_a - v_b}$$

Where:

- e = coefficient of restitution
- v_a = initial velocity of object A (before collision)
- v_b = initial velocity of object B (before collision)
- v_a' = final velocity of object A (after collision)
- v_b' = final velocity of object B (after collision)

Velocities of object A&B after collision:

$$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$

where:

- m_A and m_B are the masses of objects A and B,
- u_A and u_B are the initial velocities of objects A and B,
- v_A and v_B are the final velocities of objects A and B.

Procedure:

1. Open Apps on Physics.
2. Tap on Elastic & Inelastic collision(for reference, see image 1).
3. Set the appropriate parameters like mass and momentum, energy, velocity for both objects can be determined. Select the type of collision (for reference, see image 2).
4. Start the simulation (for reference, see image 3).

5. Perform the experiment for different parameters.

Calculation:

- Mass of object 1: $m_1 = 0.5\,\text{kg}$
- Velocity of object 1 before the collision: $u_1 = 0.5\,\text{m/s}$
- Velocity of object 2 before the collision: $u_2 = 0.4\,\text{m/s}$

For Elastic collision:

Final velocities:

$$v_1 = \frac{(0.5-0.5)\times 0.5 + 2\times 0.5\times 0.4}{0.5+0.5} = \frac{0+0.4}{1} = 0.4\,\text{m/s}$$

$$v_2 = \frac{2\times 0.5\times 0.5 + (0.5-0.5)\times 0.4}{0.5+0.5} = \frac{0.5+0}{1} = 0.5\,\text{m/s}$$

Thus, after the elastic collision:

- Final velocity of object 1: $v_1 = 0.4\,\text{m/s}$
- Final velocity of object 2: $v_2 = 0.5\,\text{m/s}$

Coefficient of Restitution:

$$e = \frac{v_2 - v_1}{u_1 - u_2} = \frac{0.5-0.4}{0.5-0.4} = \frac{0.1}{0.1} = 1$$

For Inelastic collision:

Final velocity:

From conservation of momentum:

$$(0.5\times 0.5) + (0.5\times 0.4) = (0.5+0.5)v_f$$

$$0.25 + 0.2 = 1v_f$$

$$v_f = \frac{0.45}{1} = 0.45\,\text{m/s}$$

In a perfectly inelastic collision, the coefficient of restitution $e = 0$ because the objects stick together and there is no rebound velocity.

This experiment can be performed for different parameters and the results are shown below.

RESULT:

Collision type	Set	Velocity (m/s)		Total Momentum (kg m/s)		Total Kinetic energy (J)	
Elastic collision	**Set 1** Wagon-1: 0.5 kg Wagon-2: 0.5 kg	**Before** Wagon-1: 0.2 Wagon-2: 0.0	**After** Wagon-1: 0.0 Wagon-2: 0.2	**Before** 0.100	**After** 0.100	**Before** 0.0100	**After** 0.0100
	Set 2 Wagon-1: 0.6 kg Wagon-2: 0.6 kg	**Before** Wagon-1: 0.2 Wagon-2: 0.1	**After** Wagon-1: 0.1 Wagon-2: 0.2	**Before** 0.180	**After** 0.180	**Before** 0.0150	**After** 0.0150
	Set 3 Wagon-1: 0.6 kg Wagon-2: 0.6 kg	**Before** Wagon-1: 0.3 Wagon-2: 0.1	**After** Wagon-1: 0.1 Wagon-2: 0.3	**Before** 0.240	**After** 0.240	**Before** 0.0300	**After** 0.0300
Inelastic collision	**Set 1** Wagon-1: 0.5 kg Wagon-2: 0.5 kg	**Before** Wagon-1: 0.2 Wagon-2: 0.0	**After** Wagon-1: 0.1 Wagon-2: 0.1	**Before** 0.100	**After** 0.100	**Before** 0.0100	**After** 0.00500
	Set 2 Wagon-1: 0.6 kg Wagon-2: 0.6 kg	**Before** Wagon-1: 0.2 Wagon-2: 0.1	**After** Wagon-1: 0.150 Wagon-2: 0.150	**Before** 0.180	**After** 0.180	**Before** 0.0150	**After** 0.00135
	Set 3 Wagon-1: 0.6 kg Wagon-2: 0.6 kg	**Before** Wagon-1: 0.3 Wagon-2: 0.1	**After** Wagon-1: 0.2 Wagon-2: 0.2	**Before** 0.240	**After** 0.240	**Before** 0.0300	**After** 0.0240

Conclusion:

As mass increases, **momentum** increases proportionally since momentum is the product of mass and velocity. However, **kinetic energy** increases with the square of velocity. If velocity remains constant, the kinetic energy will increase more significantly with mass. If velocity increases (mass constant), momentum and kinetic energy also increase.

To conclude, this experiment illustrates the difference between elastic and perfectly inelastic collisions. In elastic collisions, both momentum and kinetic energy are conserved. The coefficient of restitution is 1. In perfectly inelastic collisions, momentum is conserved, but kinetic energy is not conserved. The objects stick together with a common final velocity, resulting in a coefficient of restitution of zero.

Factor	Elastic Collision	Inelastic Collision
Mass	Affects final velocities; larger mass = smaller velocity change.	Affects momentum transfer but some energy is lost.
Velocity	Both velocity and mass determine final speeds; kinetic energy is conserved.	Momentum is conserved, but kinetic energy is lost as heat, sound, etc.
Energy Conservation	Kinetic energy is conserved.	Kinetic energy is not conserved, some energy is lost.
Final Speed	Determined by mass and velocity; no energy loss.	Final speed is lower due to energy loss.
Example	Bouncing ball, spacecraft in space.	Car crash, ball not bouncing back.

TYPE OF COLLISION	COEFFICIENT OF RESTITUTION	DESCRIPTION
PERFECTLY ELASTIC	$e=1$	Both momentum and kinetic energy are conserved.
PERFECTLY INELASTIC	$e=0$	The objects stick together after collision. There is maximum loss in kinetic energy. Only momentum is conserved.
PARTIALLY ELASTIC	$0<e<1$	Some kinetic energy is lost, but not all.
SUPER ELASTIC	$e>1$	The objects rebound with more kinetic energy than before the collision. It can occur under special conditions like in certain explosive or high-energy impacts.

References: https://www.walter-fendt.de/html5/phen/

Image 1: Elastic & Inelastic collision Practical Demonstration

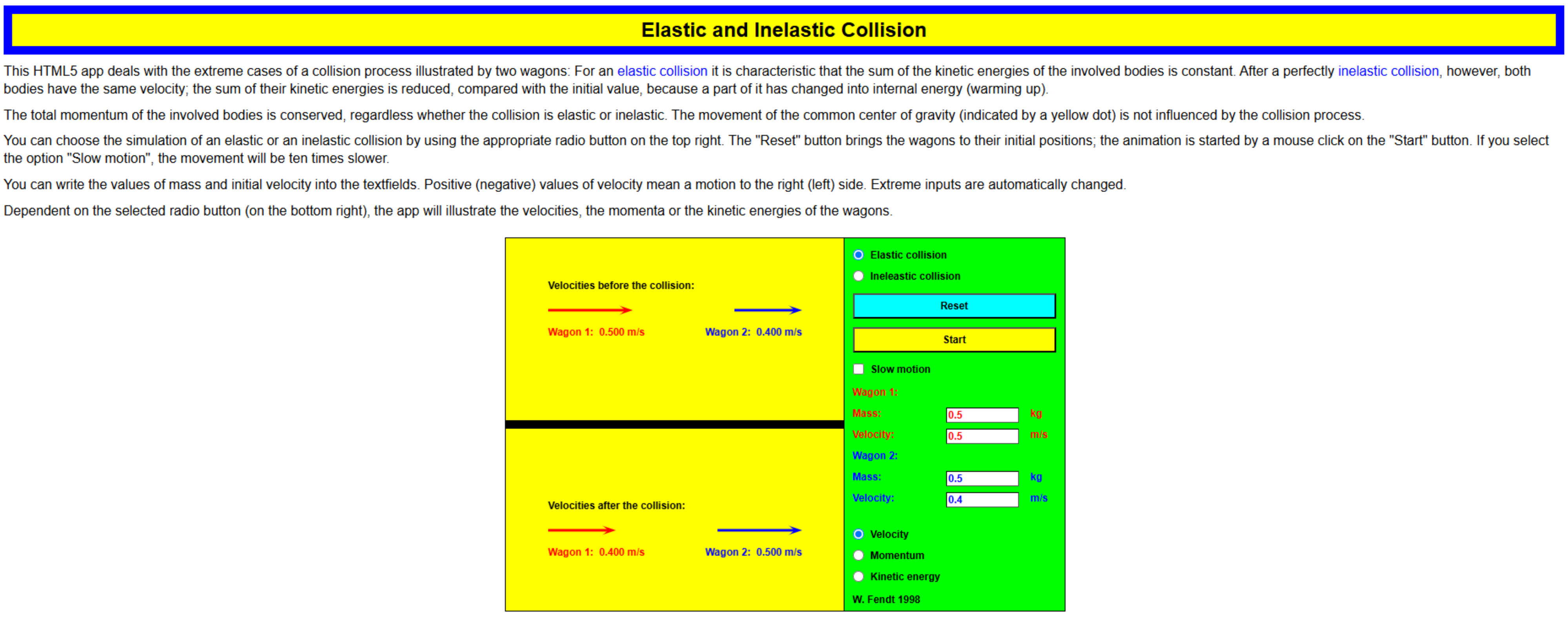
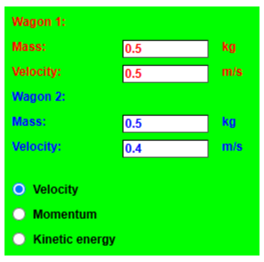


Image 2: set the type of collision & vary different parameters

type of collision

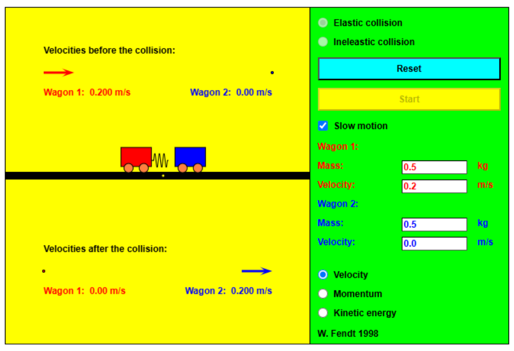


different parameters

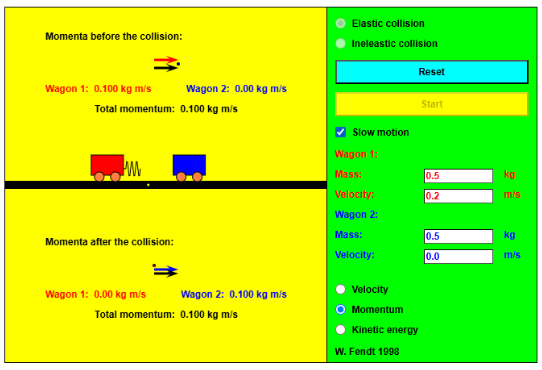
Demonstration for set-1

Elastic collision:

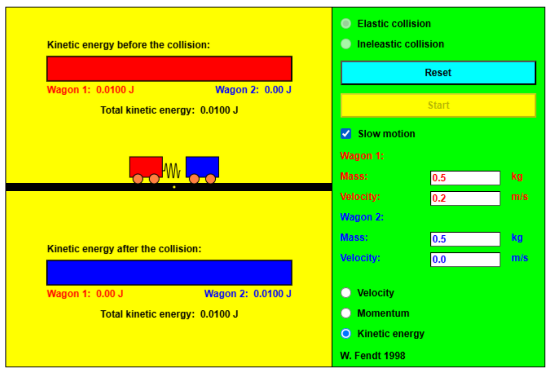
Collision type	**Set**	**Velocity (m/s)**		**Total Momentum (kg m/s)**		**Total Kinetic energy (J)**	
Elastic collision	**Set 1** Wagon-1: 0.5 kg Wagon-2: 0.5 kg	Before Wagon-1: 0.2 Wagon-2: 0.0	After Wagon-1: 0.0 Wagon-2: 0.2	Before 0.100	After 0.100	Before 0.0100	After 0.0100



(velocity)



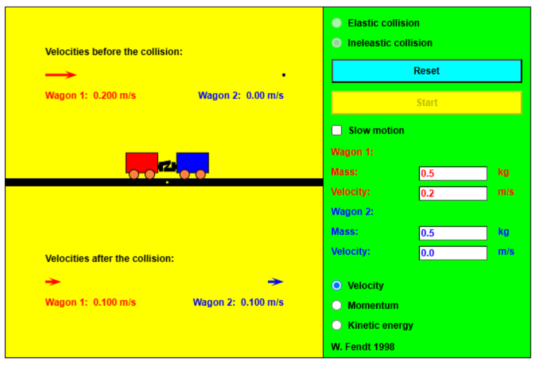
(momentum)



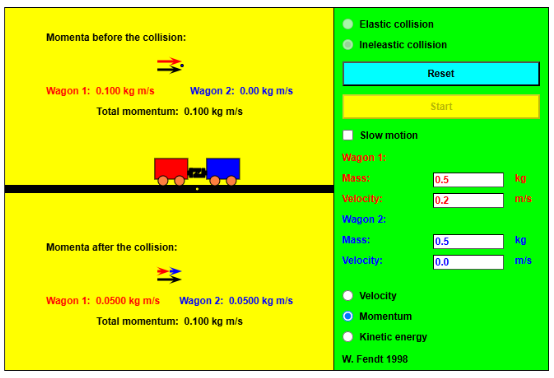
(kinetic energy)

Inelastic collision:

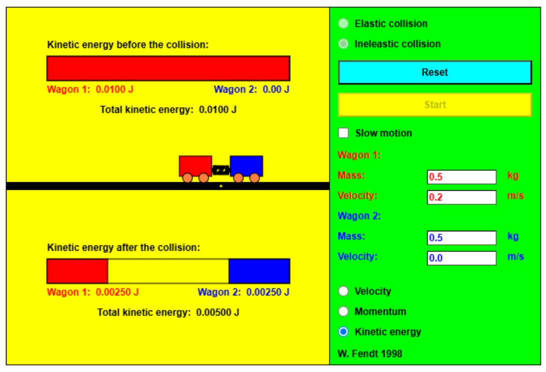
Inelastic collision	**Set 1** Wagon-1: 0.5 kg Wagon-2: 0.5 kg	Before Wagon-1: 0.2 Wagon-2: 0.0	After Wagon-1: 0.1 Wagon-2: 0.1	Before 0.100	After 0.100	Before 0.0100	After 0.00500



(velocity)



(momentum)



(kinetic energy)

Image 3: Start (or reset) the practical.