Collisions in 1D

Lesson 3

Objectives

- explain, qualitatively, that momentum is conserved in an isolated system.
- explain, quantitatively, that momentum is conserved in one and two-dimensional interactions in an isolated system
- define, compare and contrast elastic and inelastic collisions, using quantitative examples, in terms of conservation of kinetic energy.

Diploma Question Alert!

Use the following information to answer the first two questions.

Communication satellites require rocket thrusters that must be fired periodically, in short bursts, to keep the satellites from drifting out of their orbits. Usually, a gas such as ammonia is heated using electrodes. The expanding hot gas is allowed to escape, which provides the thrust. Unfortunately, the ammonia erodes the electrodes, eventually rendering them useless.

An alternative method to heat the ammonia uses microwaves. A 1.00×10^3 W microwave generator is used. The microwaves in the thrusters heat the gas to tens of thousands of degrees.

Numerical Response

1. A satellite has a mass of 172 kg. To correct its orbit, a thruster is fired for 2.27 s, which changes the velocity of the satellite by 5.86×10^{-3} m/s. The force generated by the thrusters, expressed in scientific notation, is $b \times 10^{-w}$ N. The value of b is _____.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Diploma Question Alert!

Use the following information to answer the next two questions.

A particular supertanker is fully loaded with oil and has a mass of 1.00×10^9 kg. The supertanker has a cruising speed of 20.0 km/h. One way to stop the ship is to reverse its engines. At maximum reverse thrust, the ship takes 32.0 min to stop.

Numerical Response

2. The momentum of the supertanker at cruising speed, expressed in scientific notation, is $b \times 10^w$ kg·m/s. The value of b is _____.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Diploma Question Alert!

Numerical Response 3

The maximum reverse thrust of the engines for the supertanker is _____ MN.

(Record your 3-digit answer on the answer sheet provided.)

Momentum is Conserved in an Isolated System

- **Isolated System: does not allow matter or energy to pass in or out.**
- **This means that:**

The sum of the initial momentum is an isolated system is the same as the sum of the final momentum in an isolated system.

- **This is a conservation law, just like matter, energy, charge...**

Conservation of Momentum

- Conservation of momentum can be written mathematically as:

$$\Sigma \vec{p}_i = \Sigma \vec{p}_f$$

- where
  - Σ is the greek symbol sigma and means "the sum of".

- **This allows us to examine a very special type of situation in physics: the collision.**

Collisions

- **There are two types of collisions we study:**

  1. Elastic Collision: objects collide and bounce back without deforming, there is no energy lost. (ex: pool balls colliding).

  2. Inelastic Collision: objects collide but deform in some way, losing energy (ex: a volleyball hitting the floor). Objects bounce back less or not at all (hit and stick).

1D Collision Example

- **A 0.25 kg volleyball is flying west at 2.0 m/s when it strikes a stationary 0.58 kg basketball dead centre. The volleyball rebounds east at 0.79 m/s. what will be the velocity of the basketball immediately after impact?**
- **Step 1: Make a free-body diagram.**
- **Step 2: Write the conservation statement.**

$$\sum \vec{p}_i = \sum \vec{p}_f$$

- **Step 3: plug and chug (mind your negatives!)**

Example

- **A 125 kg bighorn ram butts heads with a younger 122 kg ram during mating season. The older ram is rushing north at 8.50 m/s immediately before collision, and bounces back at 0.11 m/s [S]. If the younger ram moves at 0.22 m/s [N] immediately after collision, what was its velocity just before impact?**

Question: was this collision elastic or inelastic?

- If the collision was elastic, then there will be a conservation of energy.

$$\sum KE_i = \sum KE_f$$

where: o = old ram
y = young ram

$$1/2m_o v_{oi}^2 + 1/2m_y v_{yi}^2 = 1/2m_o v_{of}^2 + 1/2m_y v_{yf}^2$$

Hit and Stick Example

- **A 1100 kg car traveling at 25 km/h [E] collides with a 1300 kg car traveling at 15 km/h [W]. After collision, the two cars stick together. What is the velocity of the cars after impact?**

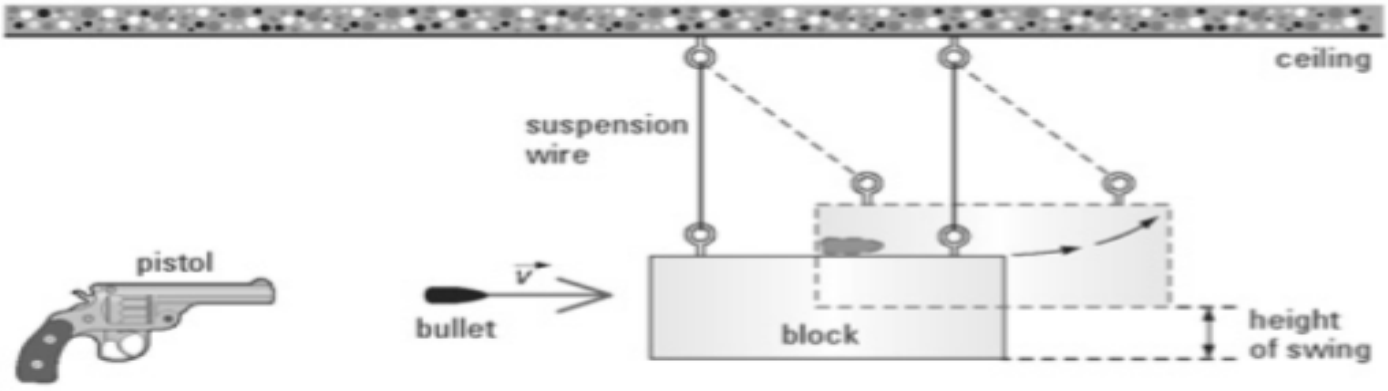
Explosion Example

- **A pizza pop of mass 250 g is initially at rest. If it is heated and explodes into two chunks, one with mass 100 g moving at 3.0 m/s left and the other with mass 150 g moving right, what is the velocity of the second chunk?**

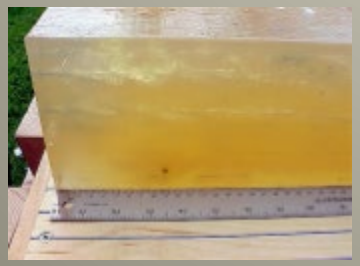
Example

- **A 0.050 kg bullet is fired from a 5.0 kg gun. If the velocity of the bullet is 275 m/s, what is the recoil velocity of the gun?**

Ballistics Pendulum example:



▲ **Figure 9.45** When a bullet is fired into the block, both the block and bullet move together as a unit after impact.



Today, ballistics gel is used to determine velocities of projectiles like bullets.

Example con't.

- **A 2.59 g bullet strikes a stationary 1.00 kg ballistic pendulum, causing the pendulum to swing up to 5.20 cm from its initial position. What was the speed of the bullet immediately before impact?**
- **Step 1: Use conservation of energy to determine velocity of the block-bullet system.**

- **Step 2: Use conservation of momentum to find the velocity of the bullet before impact.**

Diploma Question Alert!

Use the following information to answer the next question.

A lump of clay with a mass of 50.0 g is moving south at a speed of 20.0 cm/s. It collides head on with a second lump of clay with a mass of 70.0 g that is moving north at a speed of 40.0 cm/s.

1. The two lumps stick together, and no external horizontal forces act on the system. The **velocity** of the combined lump after the collision is

   A. 60.0 cm/s, south

   B. 31.7 cm/s, south

   C. 20.0 cm/s, north

   D. 15.0 cm/s, north

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Numerical Response

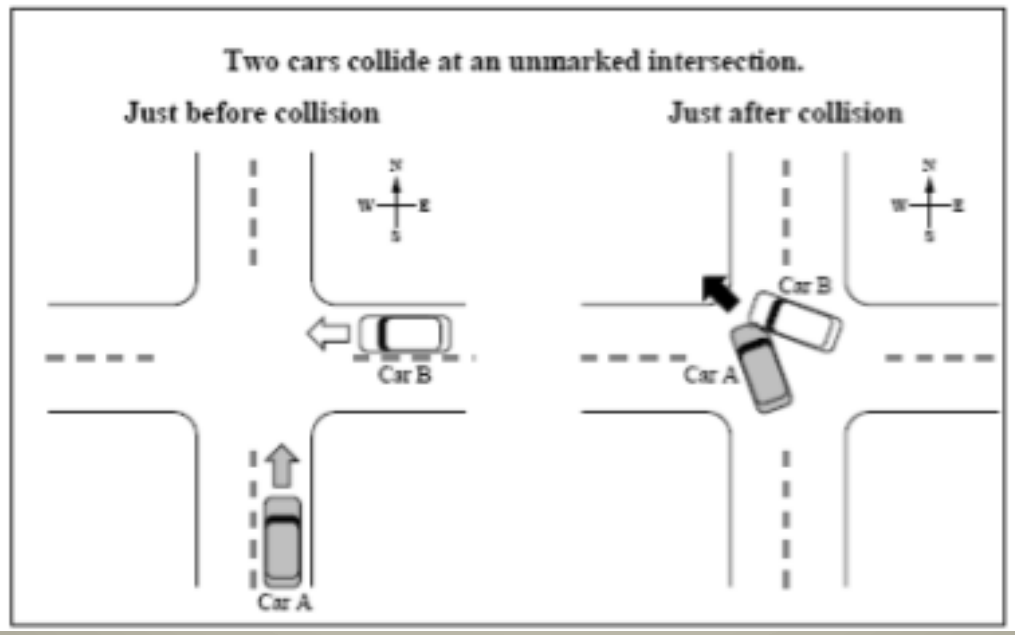
1. A 2 100 kg van collides with a 1 200 kg car that is at rest. They lock together and move together at a speed of 4.50 m/s. The initial speed of the van is _____ m/s.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Diploma Question Alert!

Use the following information to answer the next question.

Two cars collide at an unmarked intersection.



9. Which of the following statements **best** describes the inelastic collision shown above?

   A. Momentum is not conserved, and kinetic energy is not conserved.
   B. Momentum is conserved, but kinetic energy is not conserved.
   C. Momentum is not conserved, but kinetic energy is conserved.
   D. Momentum is conserved, and kinetic energy is conserved.