

# MODULE 16

## MOMENTUM DAN COLLISION 2

### 1. EXPERIMENT AIM

- 1.1. To compare the momentum before and after collisions.
- 1.2. To compare the kinetic energy before and after collisions.

### 2. EXPERIMENT APPARATUS

- 1.1. LabQuest Stream interface (1)
- 1.2. PC with LoggerPro application (1)
- 1.3. Motion detector with its holder (1)
- 1.4. 500-gram mass block (4)
- 1.5. Ejection carriages (1)
- 1.6. Track (1)
- 1.7. Magnet (4)
- 1.8. Velcro® (4)
- 1.9. Waterpass (1)



Figure 16.1. The apparatus.

### 3. BASIC CONCEPTS

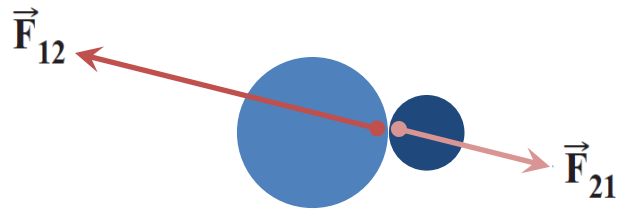
Momentum is defined as multiplication of body mass and its velocity. Physically, momentum can be explained as how hard a body changes its course. Mathematically, the equation can be written as:

$$\vec{p} = m\vec{v} \quad (16.1)$$

which  $p$  is momentum (kg m/s),  $m$  is mass (kg), and  $v$  is velocity (m/s). The total force of an object results in a change in the object's momentum over time as formulated as follows:

$$\Sigma \vec{F} = \frac{d\vec{p}}{dt} \quad (16.2)$$

$$\Sigma \vec{F} = m\vec{a} \quad (16.3)$$



**Figure 16.2.** The interaction of two particles by observing the contact force between the objects.

Suppose two particles interact with each other without being influenced by their environment (external force) and fulfill the law of action-reaction (Newton's third law), then the law of conservation of momentum applies which mathematically can be written as follows:

$$\vec{F}_{12} + \vec{F}_{21} = 0 \quad (16.4)$$

By utilizing equation (16.2) equation (16.4) can be written:

$$\frac{d}{dt}(\vec{p}_1 + \vec{p}_2) = 0 \quad (16.5)$$

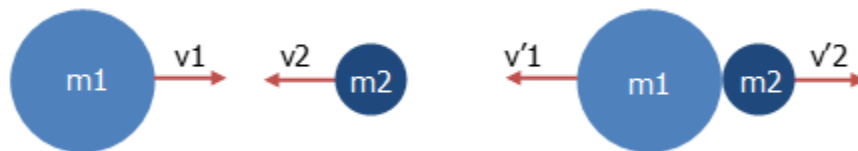
Since the derivative of the momentum of the system with respect to time is zero, it can be said that the momentum of the system is conserved. This is known as the law of conservation of linear momentum.

$$\vec{p}_1 + \vec{p}_2 = \vec{p}'_1 + \vec{p}'_2 \quad (16.6)$$

By utilizing equations (16.1) obtained:

$$m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}'_1 + m_2\vec{v}'_2 \quad (16.7)$$

Collisions are an example of a state with conserved momentum. There are three types of collisions, namely elastic collisions, partial elastic collisions and non-elastic collisions. In an elastic collision, no kinetic energy is lost so that the initial kinetic energy is equals to the final kinetic energy (the law of conservation of kinetic energy applies). In an elastic collision, some of the kinetic energy is lost so that the initial kinetic energy is not the same as the final kinetic energy. Whereas in an inelastic collision, the two colliding objects move together with the same final velocity.

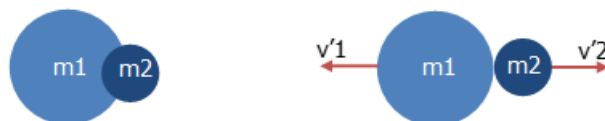


**Figure 16.3.** The elastic collision scheme between two particles ( $v'_1 = v'_2 = v$ ).. (Left) Before collision, (Right) after collision.



**Figure 16.4.** The nonelastic collision scheme between two particles. **(Left)** Before collision, **(Right)** after collision.

both masses at rest



**Figure 16.5.** The explosion scheme between two particles. **(Left)** Before collision, **(Right)** after collision.

In **Figure 16.3 (Left)** object 1 with mass  $m_1$  moves to the right (toward object 2) with velocity  $v_1$  while object 2 with mass  $m_2$  moves to the left (towards object 1) with velocity  $v_2$ . The kinetic energy before the collision is:

$$EK = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 \quad (16.8)$$

While the energy of the system after the collision is written as follows:

$$EK' = \frac{1}{2} m_1 v_1'^2 + \frac{1}{2} m_2 v_2'^2 \quad (16.9)$$

## 4. EXPERIMENT PROCEDURE (SOP)



### 3.1. TOOL SETTING

1. Prepare various tools and materials used for this practicum experiment.
2. Mount the motion detector on the stand and place it on both ends of the rail with the detector facing the rail.
3. Select the sensitivity mode on the motion detector to “Track” mode as in **Figure 16.6**.



**Figure 16.6.** Mode *track* pada sensor gerak.

4. Adjust the height of the rail until its position is completely flat, check it using a water pass.
5. Connect motion detector to digital socket (DIG) on the LabQuest Stream.
6. Open the LoggerPro application on the PC, run the data recording program. Set the program so that the speed versus time graph appears on the screen.

7. Place magnets on one side of the cart and Velcro® on the other.
8. Mount the two cart on the Velcro® section and place them in the center position of the rails.
9. Calibrate the sensor by pressing the button  Zero on the program.
10. Press the button  Collect to start collecting data.
11. Give the cart an early force until it moves slowly. Catch the cart before it reaches the end of the rail as in **Figure 16.7**. Ensure that the graphic form of the readings from the two sensors resembles a mirror image.

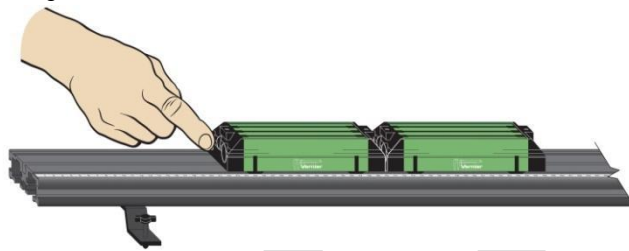


Figure 16.7. Testing Scheme of Equipment and Detector Sets.

### 3.2. EXPERIMENT 1: ELASTIC COLLUSION


1. Take measurements of the mass of both carts and the four additional weights.
2. Set the position of the two carts so that the magnetized sides are facing each other and are 40 cm apart.
3. Do the exercise by pushing one cart towards the other so that the two carts "bump" without touching. Repeat until the cart speed is neither too small nor too large.
4. Place cart 1 in the center position of the tracks, and cart 2 at a distance of 20 cm in front of one of the motion detectors.
5. Select the button  Collect to start collecting data.
6. When you hear a sound from the detector, give a push on cart 2 until it moves towards cart 1 and a collision occurs. Put a mark in the second at which the collision occurred.
7. Record the speed of each cart just before and after the collision (don't forget that velocity is a vector quantity). Write the results in the table 16.1.
8. Repeat steps 4-7 by varying the added load for each cart.

Table 16.1. Object Velocities Data on Elastic Collisions

Cart 1				Cart 2			
Mass	Mass (kg)	$v_1$ (m/s)	$v'_1$ (m/s)	Mass	Mass (kg)	$v_2$ (m/s)	$v'_2$ (m/s)

### 3.3. EXPERIMENT 2: INELASTIC COLLUSION

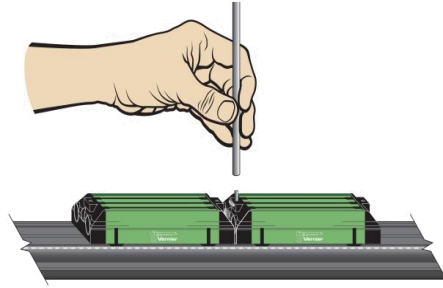
1. Set position of both carts so that the Velcro® attached sides face each other.
2. Do the exercise by pushing one of the carts towards the other so that the two carts bump into each other and then stick to each other without any significant reflections.
3. Place cart 1 in the middle position of the tracks, and cart 2 at a distance of 20 cm in front of one of the motion detectors.
4. Select the button  to start collecting data.
5. When you hear a sound from the detector, give a push on cart 2 until it moves towards cart 1 and a collision occurs. Put a mark in the second at which the collision occurred.
6. Record the speed of each cart just before and after the collision (don't forget that velocity is a vector quantity). Write the results in the table 16.2.
7. Repeat steps 3-6 by varying the added load for each cart.

Table 16.2. Object Velocities Data on Inelastic Collisions.

Cart 1				Cart 2			
Mass	Mass (kg)	$v_1$ (m/s)	$v'_1$ (m/s)	Mass	Mass (kg)	$v_2$ (m/s)	$v'_2$ (m/s)

### 3.4. EXPERIMENT 3: EXPLOSION

1. Set the position of the two carts so that the ejector attached side of one cart is facing the other.
2. Make sure the ejector is into the cart position.
3. Place two carts in the middle of the tracks so that two carts touch each other.
4. Select the button  to start collecting data.
5. When you hear the sound from the detector, press the button to quickly release the thrower on the cart (use the blunt tip of a pen or pencil) as shown in **Figure 16.8**.
6. Catch both carts before exiting the end of the tracks.
7. Record the speed of each cart just before and after the collision (don't forget that velocity is a vector quantity). Write the results in the table.
8. Repeat steps 1-7 by varying the increase in load for each cart.



**Figure 16.8.** Explosion experiment

**Table 16.3.** Object Velocities Data on Explosion.

Cart 1				Cart 2			
Mass	Mass (kg)	$\underline{v}_1$ (m/s)	$\underline{v}'_1$ (m/s)	Mass	Mass (kg)	$\underline{v}_2$ (m/s)	$\underline{v}'_2$ (m/s)

## 5. REPORT

### 4.1. EXPERIMENT 01: ELASTIC COLLUSION

1. Calculate the momentum of each cart before and after the collusion. Write the results in Table 16.4.
2. Compare the momentum values for each train when the masses of the two trains are the same. What is the value when the masses of the two trains differ. Describe the results obtained.
3. Compare the momentum of the system before and after the collision. Did the results match your estimates? Explain.
4. Calculate total kinetic energy of the two systems. Write the results in Table 16.5

**Table 16.4.** Momentum in Elastic Collision.

Before			After			$\frac{p'_{system}}{p_{system}}$ (%)
$\underline{p}_1$ (kgm/s)	$\underline{p}_2$ (kgm/s)	$\underline{p}_{system}$ (kgm/s)	$\underline{p}'_1$ (kgm/s)	$\underline{p}'_2$ (kgm/s)	$\underline{p}'_{system}$ (kgm/s)	

**Table 16.5.** Kinetic Energy in Elastic Collision.

Before			After			$\frac{EK'_{system}}{EK_{system}}$ (%)
$EK_1$ (J)	$EK_2$ (J)	$EK_{system}$ (J)	$EK'_1$ (J)	$EK'_2$ (J)	$EK'_{system}$ (J)	

**4.2. EXPERIMENT 2: INELASTIC COLLUSION**

1. Calculate the momentum on each train before and after the collision. Write the results in Table 16.6.
2. Compare the momentum values for each train when the masses of the two trains are the same. What is the value when the masses of the two trains differ. Describe the results obtained.
3. Compare the momentum of the system before and after the collision. Did the results match your estimates? Explain.
4. Calculate the total kinetic energy in both systems. Write in Table 16.7.

**Table 16.6.** Momentum in Inelastic Collision.

Before			After			$\frac{p'_{system}}{p_{system}}$ (%)
$\underline{p_1}$ (kgm/s)	$\underline{p_2}$ (kgm/s)	$\underline{p_{system}}$ (kgm/s)	$\underline{p'_1}$ (kgm/s)	$\underline{p'_2}$ (kgm/s)	$\underline{p'_{system}}$ (kgm/s)	

**Table 16.7.** Kinetic Energy in Inelastic Collision.

Before			After			$\frac{EK'_{system}}{EK_{system}}$ (%)
$EK_1$ (J)	$EK_2$ (J)	$EK_{system}$ (J)	$EK'_1$ (J)	$EK'_2$ (J)	$EK'_{system}$ (J)	

### 4.3. EXPERIMENT 3: EXPLOSION

1. Calculate the momentum on each train before and after the explosion. Write the results in Table 16.8.
2. Describe the results obtained in Table 16.8. How should the percentage value differ between the initial and final condition?
3. Describe the energy changes that occur in the case of an explosion.
4. Compare the three cases in this experiment based on the data and calculations obtained.

Table 16.8. Momentum in Explosion.

Before			After			$\frac{p'_{system}}{0,5( p'_{1} + p'_{2} )}$ (%)
$\underline{p_1}$ (kgm/s)	$\underline{p_2}$ (kgm/s)	$\underline{p_{system}}$ (kgm/s)	$\underline{p'_1}$ (kgm/s)	$\underline{p'_2}$ (kgm/s)	$\underline{p'_{system}}$ (kgm/s)	

### 6. REFERENCES

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