MODULE 13

MOMENTUM AND COLLISIONS

1. EXPERIMENT AIM

1.1 To comprehend the principle of conservation of momentum,

1.2 To calculate velocities of the system at various states of collision,

1.3 To compare the momentum before and after a collision,

1.4 To compare the kinetic energy before and after a collision,

1.5 To observe various events of collision possible of two objects.

2. EXPERIMENT APPARATUS

2.1. Air Track set*,*

2.2. Photogate sensor,

2.3. Mini LabQuest,

2.4. Lattices,

2.5. Gliders,

2.6. Weights,

2.7. Weighing scale.

3. BASIC THEORY

In this module, phenomena common to our daily life will be studied, that is the phenomena of impulse and momentum.

3.1. Momentum

Momentum of an object is defined as multiplication of its mass with its velocity. Momentum represents a measure of how difficult to alter the tendency of an object's motion. Mathematically, linear momentum is formulated as follows.

$$p = m.v \tag{13.1}$$

where *m* is the object's mass and *v* is its velocity. The total force applied to the object causes change in the momentum over time as formulated in the following equation.

$$\sum F = \frac{dp}{dt} \quad (13.2)$$

$$= \frac{d\,(mv)}{dt}$$

$$= m\frac{dv}{dt}$$

$$\sum F = m\,a \quad (13.3)$$

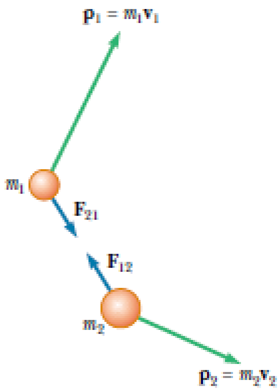

Figure 13.1. Interaction of 2 particles with momentum p_1 of particle 1 and p_2 of particle 2.

Suppose two particles interacting one each other without being disturbed by the environment (external forces) and satisfying **the law of action-reaction (Newton's third law)**. Then, the law of conservation of momentum is able to be written mathematically as

$$F_{12} + F_{21} = 0$$

$$\frac{dp_1}{dt} + \frac{dp_2}{dt} = 0$$

$$\frac{d(p_1+p_2)}{dt} = 0$$

$$p_1 + p_2 = \text{constant} \quad (13.4)$$

3.2. Impulse

Impulse could be derived from the integral of force (F) with respect to time (t). Mathematically, impulse is written as

$$F = \frac{dp}{dt}$$

$$dp = F\,dt$$

$$I = \int_{t1}^{t2} F\,dt = \int_{p1}^{p2} dp = p_2 - p_1 = \Delta p \qquad (13.5)$$

3.3. Collision

Collision is an example of situation with conserved momentum. There are three kinds of collision, i.e. perfectly elastic collision, inelastic collision, and perfectly inelastic collision. In perfectly elastic collision case, there is no energy kinetic loss during the process so that conservation of kinetic energy applies. In inelastic collision case, some kinetic energy is lost, thus causing the final kinetic energy not same as the initial one. In perfectly inelastic collision, the two colliding objects stick together after the impact and move with the same velocity.

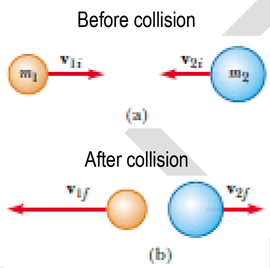

Figure 13.2. Elastic collision of two particles: (a) before collision and (b) after collision.

Figure 13.2 (a) shows particle 1 with mass m_1 moving right toward to particle 2 with a speed v_1 while particle 2 with mass m_2 moving left toward to particle 1 with a speed v_2. The total kinetic energy before the collision is

$$K_i = \frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 \qquad (13.6)$$

and after the collision is

$$K_i = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2. \qquad (13.7)$$

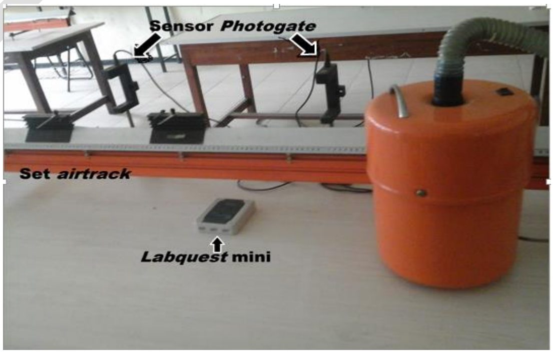

Figure 13.3. Components of the momentum and collision experiment.

4. EXPERIMENT METHODS

4.1 Experiment instrument settings

a. Prepare two photogate sensors and connect them to LabQuest,

b. Change setting in mini LabQuest setting on computer to photogate sensor,

c. Place the first photogate sensor at a distance of 50 cm and the second photogate sensor at a distance of 150 cm,

d. Prepare the glider by attaching some additional weights and lattices,

e. Put the glider on the air track,

f. Turn the air track on and adjust the air track holders to align the air track horizontally (not tilted). Horizontally aligned air track causes no slope, thus the glider put on it will stand still when the air track is on.

4.2 Collision 1

a. Put two gliders each on the end of the air track,

b. Prepare the LabQuest to start reading the data,

c. Push the gliders carefully and make sure that they collide in the region located between the two photogate sensors,

d. Write the time readings of the sensor,

e. Calculate speeds before and after the collision of each gliders,

f. Repeat the steps for various weights attached on the gliders,

g. Tabulate the data on Table 13.1.

Table 13.1. Data of mass, initial speed, and final speed in collision 1.

Variation	Glider 1			Glider 2		
	Mass (kg)	Initial Speed (m/s)	Final Speed (m/s)	Mass (kg)	Initial Speed (m/s)	Final Speed (m/s)
1						
2						
3						
4						
5						

h. From Table 13.1, calculate coefficient of restitution of each variations and tabulate the results on the following table.

Table 13.2. Data of coefficient of restitution in collision 1.

Variation	Coefficient of restitution (e)
1	
2	
3	
4	
5	

i. From Table 13.1, determine momentum of the gliders and total momentum of the system before and after the impact. Tabulate the results on the following table.

Table 13.3. Data of momentum of glider 1, glider 2, and the system before and after the impact in collision 1.

Variation	Before Collision			After Collision		
	p glider 1 (kg m/s)	*p* glider 2 (kg m/s)	*p* system (kg m/s)	*p* glider 1 (kg m/s)	*p* glider 2 (kg m/s)	*p* system (kg m/s)
1						
2						
3						
4						
5						

j. Calculate kinetic energy of the system before and after the impact. Compare and tabulate the results on the following table.

Table 13.4. Data of kinetic energy (KE) before and after the impact in collision 1.

Variation	Initial KE (J)	Final KE (J)
1		
2		
3		
4		
5		

4.3. Collision 2

a. Put the first glider on the end of the air track and the other glider between the two photogate sensors. Make sure the second glider is not moving,

b. Prepare the LabQuest to start reading the data,

c. Push the glider on the end of the air track carefully and let it collide with the second glider,

d. Write the time readings of the sensor,

e. Calculate speeds before and after the collision of each gliders,

f. Repeat the steps for various weights attached on the gliders,

g. Tabulate the data on Table 13.5.

Table 13.5. Data of mass, initial speed, and final speed in collision 2.

Variation	Glider 1			Glider 2		
	Mass (kg)	Initial Speed (m/s)	Final Speed (m/s)	Mass (kg)	Initial Speed (m/s)	Final Speed (m/s)
1						
2						
3						
4						
5						

h. From Table 13.5, calculate coefficient of restitution of each variations and tabulate the results on the following table.

Table 13.6. Data of coefficient of restitution in collision 2.

Variation	Coefficient of restitution (e)
1	
2	
3	
4	
5	

i. From Table 13.5, determine momentum of the gliders and total momentum of the system before and after the impact. Tabulate the results on the following table.

Table 13.7. Data of momentum of glider 1, glider 2, and the system before and after the impact in collision 2.

Variation	Before Collision			After Collision		
	p glider 1 (kg m/s)	*p* glider 2 (kg m/s)	*p* system (kg m/s)	*p* glider 1 (kg m/s)	*p* glider 2 (kg m/s)	*p* system (kg m/s)
1						
2						
3						
4						
5						

j. Calculate kinetic energy of the system before and after the impact. Compare and tabulate the results on the following table.

Table 13.8. Data of kinetic energy (KE) before and after the impact in collision 2.

Variation	Initial KE (J)	Final KE (J)
1		
2		
3		
4		
5		

4.4. Collision 3

a. Put one glider on the end of the air track and put a rigid body between the two photogate sensors,

b. Prepare the LabQuest to start reading the data,

c. Push the glider on the end of the air track carefully and let it collide with the rigid body located between the photogate sensors,

d. Write the time readings of the sensor,

e. Calculate speeds before and after the collision of the glider,

f. Repeat the steps for various weights attached on the glider,

g. Tabulate the data on Table 13.9.

Table 13.9. Data of mass, initial speed, and final speed in collision 3.

Variation	Glider 1		
	Mass (kg)	Initial Speed (m/s)	Final Speed (m/s)
1			
2			
3			
4			
5			

h. From Table 13.5, calculate coefficient of restitution of each variations and tabulate the results on the following table.

Table 13.10. Data of coefficient of restitution in collision 3.

Variation	Coefficient of restitution (e)
1	
2	
3	
4	
5	

i. From Table 13.9, determine momentum of the glider and total momentum of the system before and after the impact. Tabulate the results on the following table.

Table 13.11. Data of momentum of glider 1 and the system before and after the impact in collision 3.

Variation	Before Collision		After Collision	
	p glider 1 (kg m/s)	*p* system (kg m/s)	*p* glider 1 (kg m/s)	*p* system (kg m/s)
1				
2				
3				
4				
5				

j. Calculate kinetic energy of the system before and after the impact. Compare and tabulate the results on the following table.

Table 13.12. Data of kinetic energy (KE) before and after the impact in collision 3.

Variation	Initial KE (J)	Final KE (J)
1		
2		
3		
4		
5		

5. REPORT

5.1 Verification of law of conservation of momentum

1. Make graphs of position as a function of time (x vs t) for the three conditions!
2. Determine speeds according to the three obtained graphs!
3. According to the data of initial and final speeds, is the law of conservation of momentum confirmed?
4. Give your analysis about this experiment!

5.2 Determination of impulse of the system

1. Determine accelerations of the system from the graph obtained in section 5.1, then make the three corresponding graph of force as a function of time!
2. Determine impulse of the system according to the obtained graphs!
3. Compare the impulses calculated according to the graphs to the one obtained from the change of momentum!
4. Give your analysis about this experiment!

6. REFERENCES

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