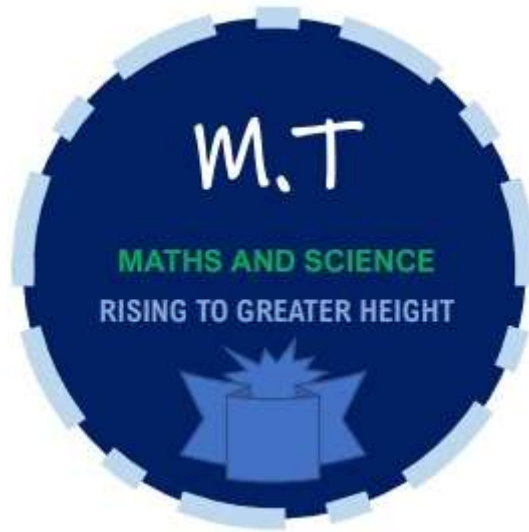




PHYSICAL SCIENCES
GRADE 12



PHYSICAL SCIENCES
GRADE 12

TOPIC:

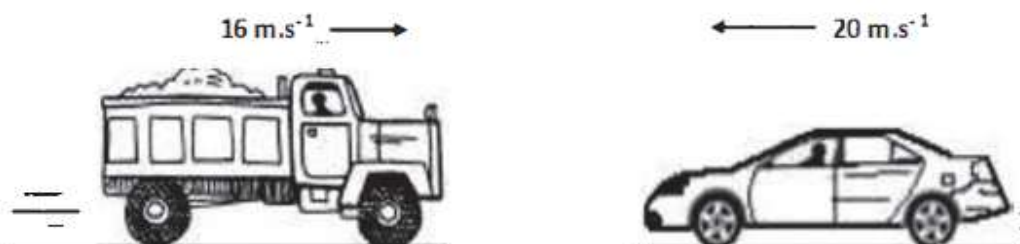
MOMENTUM AND IMPULSE



MOMENTUM
MOMENTUM, IMPULSE, SECONDS LAW IN TERMS OF MOMENTUM, THE PRINCIPLE OF CONSERVATION OF MOMENTUM and ELASTIC and INELASTIC COLLISION

ACTIVITY 1 23EM

A 1500 kg car is travelling west at 20 m.s^{-1} on a horizontal frictionless track. It collides with a 2600 kg truck travelling at 16 m.s^{-1} east. After the collision, the car travels at $5,2 \text{ m.s}^{-1}$ east. See the diagram below.



- 4.1 State the *principle of conservation of linear momentum* in words. (2)
- 4.2 Calculate the velocity of the truck immediately after the collision. (4)
- 4.3 Determine by means of relevant calculations whether the collision is ELASTIC or INELASTIC. (5)
- 4.4 Which ONE of the vehicles (CAR or TRUCK) that will experience a greater amount of damage during collision? Explain your answer. (2)

[13]

ACTIVITY 2 ES25

A truck of mass 4 000 kg is travelling at $32,17 \text{ m}\cdot\text{s}^{-1}$ to the right on a straight horizontal road. At the same time a car of mass 2 000 kg is travelling at $25 \text{ m}\cdot\text{s}^{-1}$ in the same direction ahead of the truck as shown in the diagram below.



The truck collided with the car and the two vehicles stick together and move as one unit. Ignore the effects of friction.

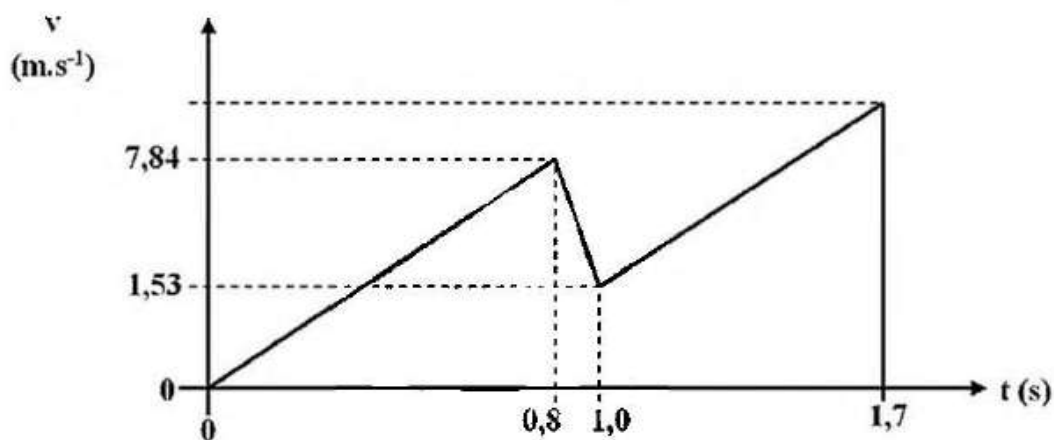
- 4.1 State the principle of conservation of linear momentum in words. (2)
- 4.2 Calculate the velocity of the truck-car-system immediately after the collision. (4)
- 4.3 Is the collision between the truck and the car ELASTIC or INELASTIC? (1)
- 4.4 On impact the truck exerts a force of magnitude **F** on the car.
 - 4.4.1 Will the magnitude of the force that the car exerts on the truck, on impact, be GREATER THAN, LESS THAN or EQUAL TO, F? (1)
 - 4.4.2 Name and state a relevant physics law that explains the answer to QUESTION 4.4.1. (3)

[11]

ACTIVITY 3 GS25

A learner tests the strength of a piece of glass by dropping a steel ball of mass 5 kg from a height of 3 m onto the glass.

The velocity-time graph below represents the motion of the steel ball from the moment the learner drops the ball until it reaches the ground.



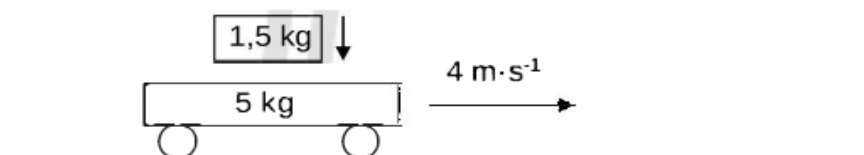
- 4.1 Define the term *momentum*. (2)
- 4.2 Calculate the net force exerted by the glass on the steel ball. (4)
- 4.3 Is this an ELASTIC or INELASTIC collision? Refer to the data in the graph and the relevant principles to explain the answer. (4)
- 4.4 The glass does not break when the learner drops a soft rubber ball of similar mass from the same height onto the glass. (3)

Use Physics principles to explain this phenomenon.

(3)
[13]

ACTIVITY 4 G23M

A trolley, mass 5 kg, moves at $4 \text{ m} \cdot \text{s}^{-1}$ east across a frictionless horizontal surface. A brick of mass 1.5 kg is dropped onto the trolley.

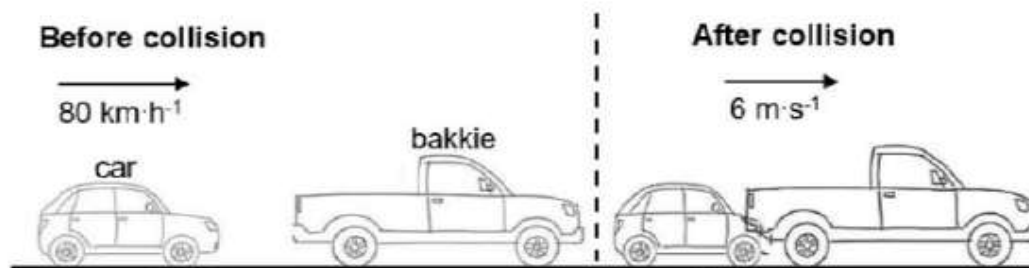


- 4.1 Define in words the *Law of Conservation of Momentum*. (2)
- 4.2 State the condition for an elastic collision. (1)
- 4.3 Calculate the change in momentum of the 5 kg trolley. (5)

[8]

ACTIVITY 5 K25M

A car of mass 1 600 kg travelling to the right at $80 \text{ km}\cdot\text{h}^{-1}$ runs into the back of a stationary bakkie of unknown mass. The two vehicles stick together and move to the right at $6 \text{ m}\cdot\text{s}^{-1}$.



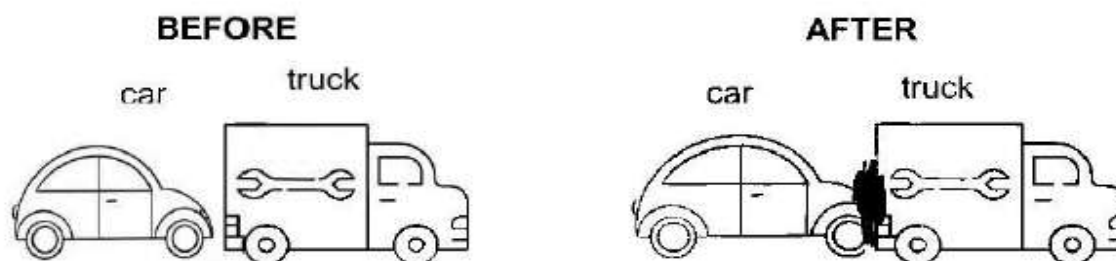
- 4.1 Convert $80 \text{ km}\cdot\text{h}^{-1}$ to $\text{m}\cdot\text{s}^{-1}$. (2)
- 4.2 Calculate the change in momentum of the car. (3)
- 4.3 Write down the magnitude and direction of the change in momentum of the bakkie. (1)
- 4.4 State the *principle of conservation of linear momentum* in words. (2)
- 4.5 Calculate the mass of the bakkie. (4)

[12]

ACTIVITY 6 F25T

A car of mass 1 200 kg moving at a speed of $25 \text{ m}\cdot\text{s}^{-1}$ in the eastern direction, crashes into the back of a truck of mass 6 000 kg moving in the same direction at $15 \text{ m}\cdot\text{s}^{-1}$. The velocity of the car after the collision is $16 \text{ m}\cdot\text{s}^{-1}$ to the east.

Ignore all frictional and rotational effects.

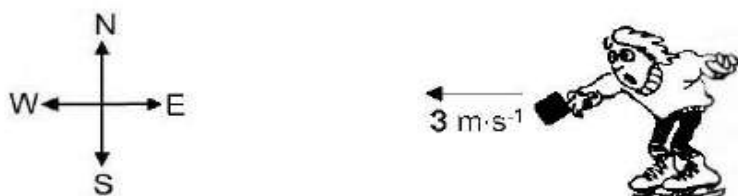


- 4.1 Write the *principle of conservation of linear momentum* in words. (2)
- 4.2 Calculate the **velocity of the truck** after the collision. (4)
- 4.3 Calculate the mechanical energy lost during the car-truck collision. (5)
- 4.4 Explain why mechanical energy is lost. (2)

[13]

ACTIVITY 7 KS25

A boy, of mass 60 kg on ice skates, is stationary on a frictionless surface. He throws an object, of mass 4 kg, at $3 \text{ m}\cdot\text{s}^{-1}$ horizontally in the westerly direction as shown in the diagram below.



At the instant the object leaves the boy's hand, the boy starts moving.

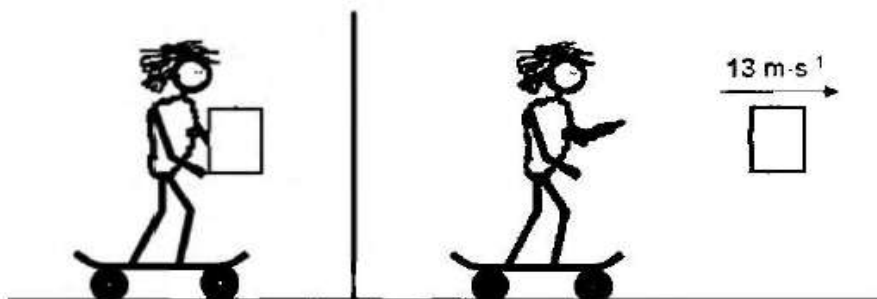
Ignore the effects of friction.

- 4.1 In which direction does the boy move? Write down only EAST or WEST. (1)
- 4.2 Name and state the law which explains the direction in which the boy experiences a force when he throws the object. (3)
- 4.3 Calculate the speed of the boy immediately after the object leaves his hand. (4)
- 4.4 How will the answer to QUESTION 4.3 be affected if:
 - 4.4.1 The boy throws the object at a higher velocity in the same direction
Choose from: INCREASES, DECREASES or REMAINS THE SAME. (1)
 - 4.4.2 The boy throws the object of double the mass at the same velocity.
Choose from: INCREASES, DECREASES or REMAINS THE SAME. (1)
 - 4.4.3 Explain the answer to QUESTION 4.4.2 (2)

[12]

ACTIVITY 8 25MS

A learner of mass 60 kg is standing on a stationary skateboard of mass 5 kg while holding a school bag of mass, m . After some time, the learner throws the school bag horizontally at a constant velocity of $13 \text{ m}\cdot\text{s}^{-1}$ to the right as shown in the diagram below. Ignore the effect of wheel rotation.



Immediately after throwing the school bag, the combined learner-skateboard system has a CHANGE IN MOMENTUM of $6,5 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1}$ to the LEFT. Assume that the system is isolated.

4.1 Explain what is meant by the term *isolated system*. (1)

4.2 Calculate the:

4.2.1 Velocity of the learner-skateboard system immediately after throwing the school bag (3)

4.2.2 Mass m of the school bag (4)

Modern cars are equipped with safety features, which play an important role in saving the lives of passengers.

4.3 Name any ONE of the safety features modern cars are equipped with. (1)

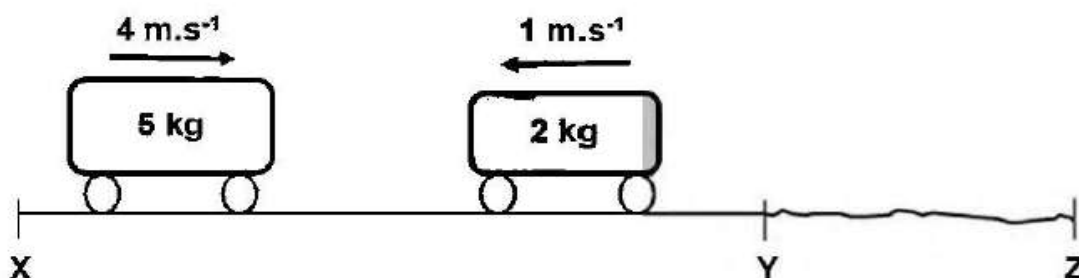
4.4 Explain using a relevant physics principle, how the safety features help in reducing the number of fatalities during accidents. (2)

[11]

ACTIVITY 9 WCT25

The diagram below shows two sections, **XY** and **YZ**, of a horizontal, flat surface. Section **XY** is frictionless, while section **YZ** is rough.

A 5 kg trolley, moving with a velocity of 4 m.s^{-1} to the right, collides head-on with a 2 kg trolley moving with a velocity of 1 m.s^{-1} towards the 5 kg trolley. After the collision, the two trolleys stick together and move to the right pass point **Y**.



4.1 State the *principle of conservation of linear momentum* in words. (2)

4.2 Calculate the magnitude of the velocity of the combined trolleys at point **Y**. (4)

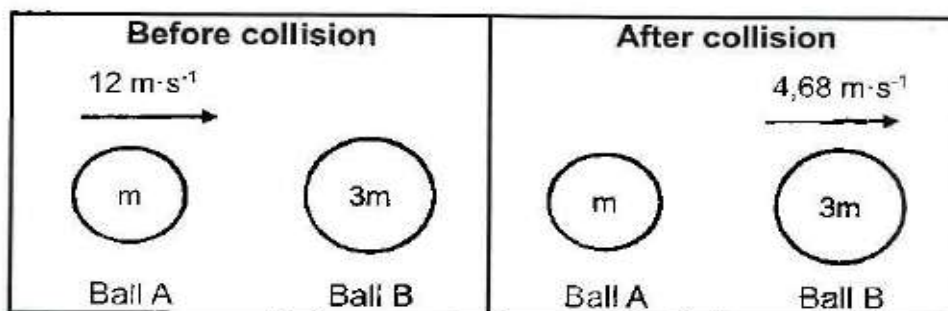
The combined trolleys travel for 0,3 s from point **Y** before coming to a stop at point **Z**.

4.3 Calculate the magnitude of the net force acting on the combined trolleys while they move through section **YZ**. (4)

[10]

ACTIVITY 10 NWT25

Ball **A** of mass m moving to the right with a speed of $12 \text{ m}\cdot\text{s}^{-1}$ collides with a stationary ball **B** of mass $3m$. After collision, ball **B** moves to the right at $4,68 \text{ m}\cdot\text{s}^{-1}$.



Ignore all frictional and rotational effects.

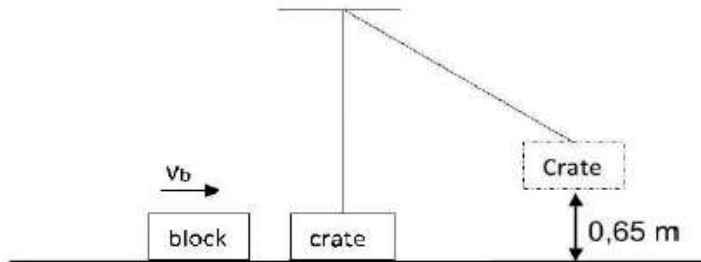
- 4.1 Calculate the velocity of ball **A** after the collision. (4)
- 4.2 Prove, showing ALL calculations, that the collision of the two balls is INELASTIC. (4)

If the value of m is $0,05 \text{ kg}$ and the balls are in contact with each other for $0,03 \text{ s}$ during the collision.

- 4.3 Define the term *impulse*. (2)
 - 4.4 Determine the force that ball **A** exerts on ball **B** during the collision. (3)
- [13]**

ACTIVITY 11 M25M

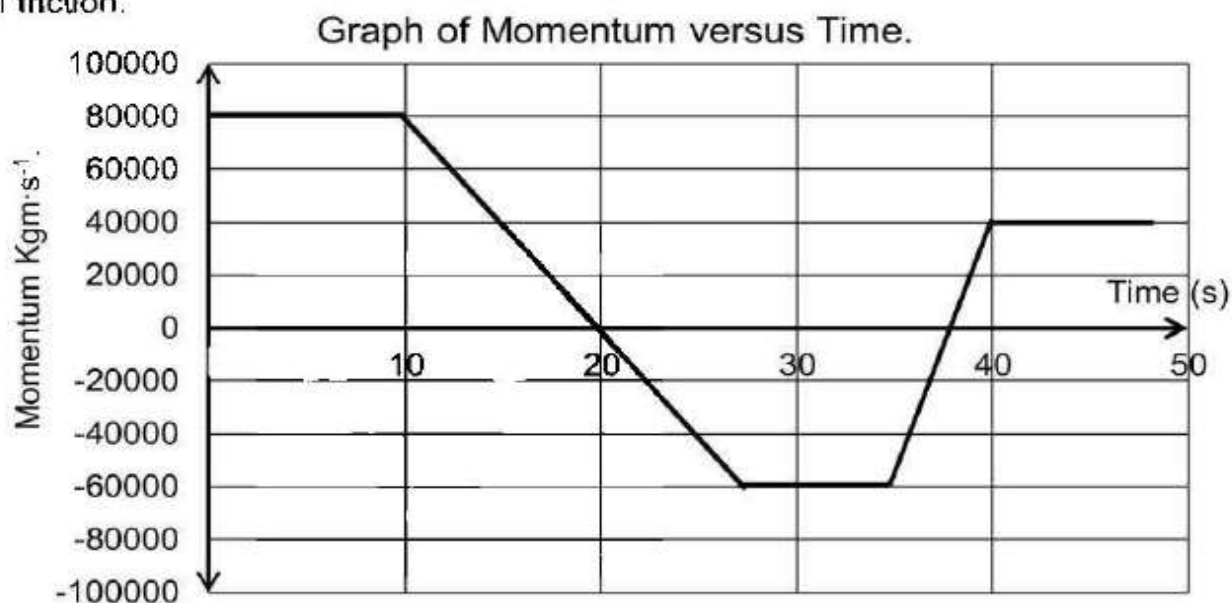
A 1,2 kg crate is attached to a long string as shown in the diagram below. A block of mass 0,4 kg collides with the stationary crate with a velocity v_b and rebounds with a velocity of $0,36 \text{ m} \cdot \text{s}^{-1}$ causing the crate to swing up through a vertical height of 0,65 m. Frictional forces are ignored.



- 4.1 State the principle of conservation of mechanical energy. (2)
 - 4.2 Calculate the magnitude of the velocity of the crate immediately after the block collided with the crate. (4)
 - 4.3 State the law of conservation of linear momentum. (2)
 - 4.4 Calculate the velocity of the block, v_b , just before it collides with the crate. (4)
- [12]**

ACTIVITY 12 F2M5

The following graph shows the change in **momentum** of a truck over a period of time. The truck is initially moving **EASTWARDS** in a straight line. Ignore the effects of friction.



- 3.1 Define the term *momentum*. (2)
- 3.2 Write down the:
 - 3.2.1 direction of the truck at $t = 30$ s. (2)
 - 3.2.2 magnitude of the net force acting on the truck for the first 10 s. (1)
- 3.3 Explain your answer to QUESTION 3.2.2. (3)
- 3.4 The truck collides with a car at $t = 35$ s. The car has a mass of 2000 kg and is moving at a constant velocity of $20\text{ m}\cdot\text{s}^{-1}$ east before the collision. After the collision, the car has a velocity to the west.



- 3.4.1 The **ACCELERATION** of the truck, between $t = 35$ s and $t = 40$ s, is $4\text{ m}\cdot\text{s}^{-2}$ east. Calculate the mass of the truck. (5)
- 3.4.2 Calculate the velocity of the truck before the collision. (3)

The sum of the kinetic energy of the car and truck after the collision is $1,06 \times 10^6 \text{ J}$.

3.4.3 Prove by means of a calculation whether the collision between the car and the truck is *ELASTIC* or *INELASTIC*.

(4)
[20]

ACTIVITY 13 24GM

A minibus taxi, travelling south at a velocity of $20 \text{ m}\cdot\text{s}^{-1}$, collides head-on with a car, of total mass $1\,248 \text{ kg}$ (including the driver), heading north with a velocity of $15 \text{ m}\cdot\text{s}^{-1}$.

After the collision, the vehicles move together at a velocity of $10 \text{ m}\cdot\text{s}^{-1}$ south.



3.1 State the *principle of conservation of linear momentum* in words. (2)

3.2 The driver of the car claims that the taxi was not only speeding but it was overloaded with passengers.

Consider the information below:

- Mass of the “empty” Taxi: $2\,000 \text{ kg}$
- Average mass of a person: 70 kg

Maximum legal occupancy of the taxi is 12 PEOPLE (including the driver)

Use the *principle of conservation of linear momentum* to determine how many passengers exceeded the legal limit for the taxi. Assume all passengers are of average mass. (5)

3.3 Do the necessary calculations to show that the collision is *INELASTIC*. (4)

3.4 Modern cars have seat belts, air bags and crumple zones to help minimize injuries during accidents.

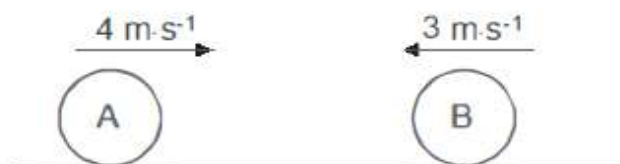


Use principles in physics to explain how the air bags and crumple zones, mentioned above, contribute to the safety of passengers.

(3)
[14]

ACTIVITY 14 FM23

Two metal balls **A** and **B** are rolling along in a horizontal straight line towards each other in a closed system. Ball **A** with a mass of $0,75 \text{ kg}$ is rolling at a speed of $4 \text{ m}\cdot\text{s}^{-1}$. Ball **B** with a mass of $1,25 \text{ kg}$ collides head on with ball **A** at a speed of $3 \text{ m}\cdot\text{s}^{-1}$. After collision ball **A** rolls in the direction opposite to its initial direction at a speed of $2,5 \text{ m}\cdot\text{s}^{-1}$.



- 3.1 Calculate the change in momentum experienced by ball **A** due to the collision. (4)
 - 3.2 Use the change in momentum of ball **B** to calculate the velocity of ball **B** after collision. (4)
 - 3.3 What is the net change in momentum for the whole system (ball **A** and ball **B**)? (1)
 - 3.4 Calculate the magnitude of the average force that ball **A** and ball **B** exert on each other during collision if the two balls are in contact for $0,2 \text{ s}$. (3)
 - 3.5 Is the collision ELASTIC or INELASTIC? Explain the answer by means of calculations. (5)
- [17]**

ACTIVITY 15 E23J

A truck of mass 5 600 kg travelling at a velocity of 10 m.s^{-1} to the east, collides with a stationary car of mass 1 800 kg. The collision lasted for 0,59 s. After the collision, the truck and the car are coupled and move together eastwards.

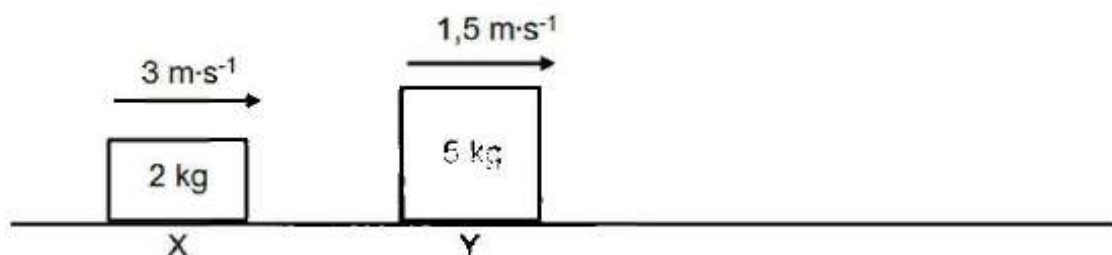


- 6.1 State the principle of the *Conservation of Linear momentum* in words. (2)
- 6.2 Calculate the:
 - 6.2.1 Velocity of the truck-car system after the collision (4)
 - 6.2.2 Force that the truck exerts on the car (5)
- 6.3 If the collision lasted three (3) times longer, how will your answer in QUESTION 6.2.2 be influenced?
Write down only INCREASE, DECREASE or SIMILAR. (1)
- 6.4 Explain your answer in QUESTION 6.3. (2)
- 6.5 Name TWO safety features that can be found in vehicles so that serious injuries can be minimised when collisions like this take place. (2)

[16]

ACTIVITY 16 L2M5

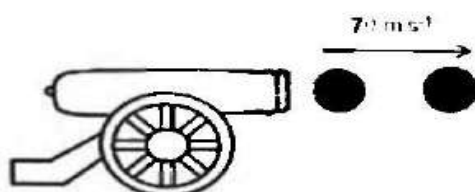
Two blocks are moving to the right along a frictionless surface. Block **X** has a mass of 2 kg and is moving at $3 \text{ m}\cdot\text{s}^{-1}$. Block **Y** has a mass of 5 kg and is travelling at $1,5 \text{ m}\cdot\text{s}^{-1}$. The blocks collide and block **Y** continues in its original direction with a speed of $2,5 \text{ m}\cdot\text{s}^{-1}$ after their collision.



- 3.1 State the principle or law which is applicable AT THE POINT OF COLLISION. (2)
 - 3.2 Give a reason why the speed of the 5 kg block increases after collision. (1)
 - 3.3 Calculate the impulse experienced by the 5 kg block. (3)
 - 3.4 Determine the magnitude of the velocity of block **X** after collision. (4)
- [10]**

ACTIVITY 17 E25M

A cannon has a mass of 2150 kg and it fires cannonballs during a routine training exercise. Each cannonball travels at a speed of $70 \text{ m}\cdot\text{s}^{-1}$ to the right when it leaves the cannon. (Take the initial velocity of the cannonball before being fired, as zero.)

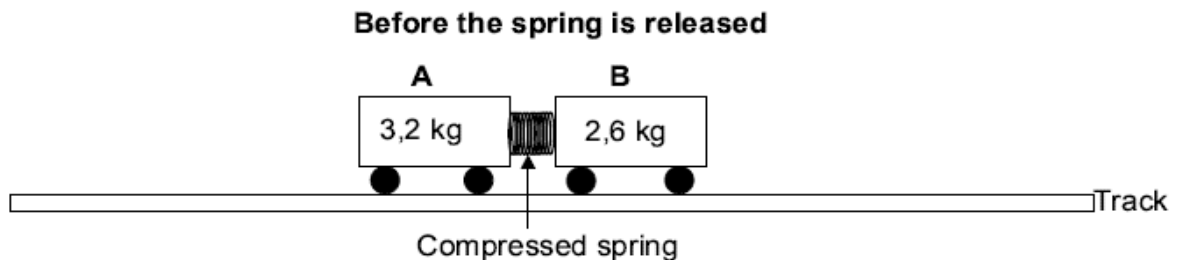


The cannon fires 100 cannon balls per minute. The mass of each cannon ball is 50g.

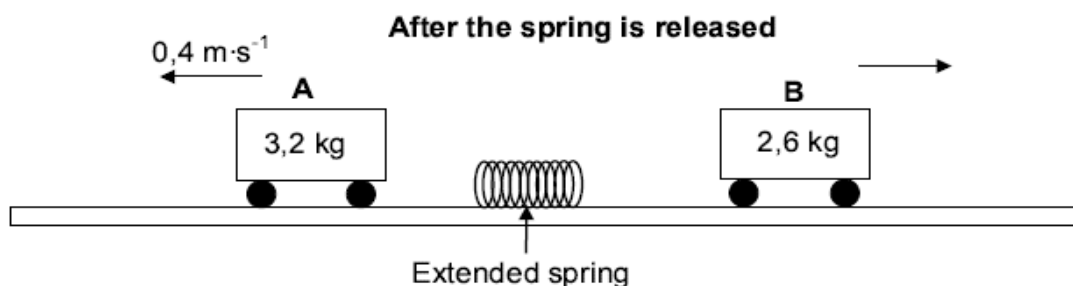
- 4.1 Define in words the term impulse (2)
- 4.2 Calculate the magnitude of:
 - 4.2.1 The momentum of each canon ball when it leaves the gun. (3)
 - 4.2.2 The net average force that each cannonball exerts on the cannon. (5)

ACTIVITY 18 M24/J

Two trolleys **A** and **B** of mass 3,2 kg and 2,6 kg respectively are held at rest on a straight horizontal, frictionless track, with a compressed spring between them, as shown in the diagram below.



After the trolleys are released, the spring extends to its natural length and then falls onto the track. Trolley **A** now moves with a constant velocity of $0,4 \text{ m}\cdot\text{s}^{-1}$ to the left, while trolley **B** moves with a constant unknown velocity to the right. Trolley **B** reaches the end of the track after 1,3 s.



- 4.1. State the *principle of conservation of linear momentum* in words. (2)
- 4.2. Calculate the distance travelled by trolley **B** in 1,3 s. (5)

The average force exerted by the extended spring on each trolley while they were in contact with the spring was 4,2 N.

- 4.3 Calculate the time it took the spring to extend to its natural length. (3)
- 4.4 Trolley **B** is now replaced by trolley **C**, which has a larger mass. The same compressed spring is placed between trolleys **A** and **C**. The trolleys are then released. The average force exerted by the extended spring on the trolleys remains at 4,2 N for the same period of time as calculated in QUESTION 4.3.

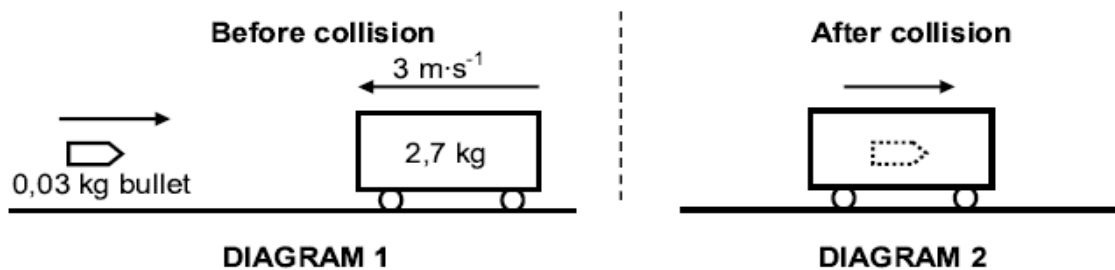
How does the magnitude of the velocity of trolley **C** compare to the magnitude of the velocity of trolley **B** after the spring has fallen to the track? Write only GREATER THAN, LESS THAN or EQUAL TO. Explain the answer.

(3)
[13]

ACTIVITY 19 N23

A wooden trolley of mass $2,7 \text{ kg}$ moves to the left with a constant velocity of $3 \text{ m}\cdot\text{s}^{-1}$. A bullet of mass $0,03 \text{ kg}$ is fired horizontally from the left towards the trolley. (See DIAGRAM 1.)

The bullet strikes the trolley and comes to rest inside the trolley in $0,02 \text{ s}$. The average net force exerted by the trolley on the bullet during this time is 591 N . The bullet-trolley combination now moves to the right. (See DIAGRAM 2.)



Ignore all frictional and rotational effects.

- | | | |
|-----|--|-------------|
| 4.1 | Write down the magnitude and direction of the average net force that the bullet exerts on the trolley. | (1) |
| 4.2 | Calculate the magnitude of the velocity with which the bullet strikes the trolley. | (4) |
| 4.3 | State the principle of conservation of linear momentum in words. | (2) |
| 4.4 | Calculate the magnitude of the velocity of the bullet-trolley combination after the collision. | (4) |
| | | [11] |

ACTIVITY 20 EJ24

A truck of mass 1 500 kg travelling at a constant speed of 20 m.s^{-1} to the west along a straight horizontal road collides with a stationary car of mass 900 kg and the two vehicles moved together after the collision. The collision lasted for 0,2 s. Ignore the effect of friction.



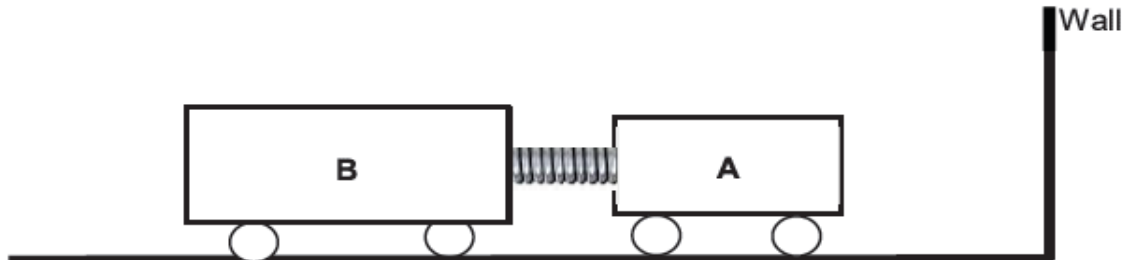
- 5.1 Explain what is meant by the term *isolated system*. (2)
- 5.2 State the principle of conservation of linear momentum in words. (2)
- 5.3 Calculate the:
 - 5.3.1 Speed of the vehicles after collision (4)
 - 5.3.2 Net force exerted by the truck on the car (4)
- 5.4 Is the collision ELASTIC or INELASTIC? Use relevant calculations to explain your answer. (5)
- 5.5 Delicate equipment is usually packaged using bubble wrap for safety of the equipment. Explain how this process keeps the equipment safe. (3)

[20]

ACTIVITY 21 ES23

Two trolleys, **A** of mass 1 kg, and **B** of mass 2 kg, are held stationary on a smooth horizontal surface with a compressed spring between them, as shown in the diagram below. The spring is released and falls to the ground. Trolley **A** moves to the right at a constant velocity of $5,0 \text{ m}\cdot\text{s}^{-1}$ and collides with a wall.

Assume this is an isolated system.



- 4.1 Define an *isolated system*. (2)
 - 4.2 Calculate the velocity of trolley **B** immediately after the spring is released. (4)
 - 4.3 The average force exerted by the wall on trolley **A** is 80 N and the collision of the trolley with the wall lasts 0,5 seconds.
Calculate the velocity with which trolley **A** moves away from the wall. (4)
 - 4.4 A learner comments that the collision of trolley **A** with the wall is inelastic.
Briefly explain what is meant by an inelastic collision. (2)
- [12]**

ACTIVITY 22 ES24

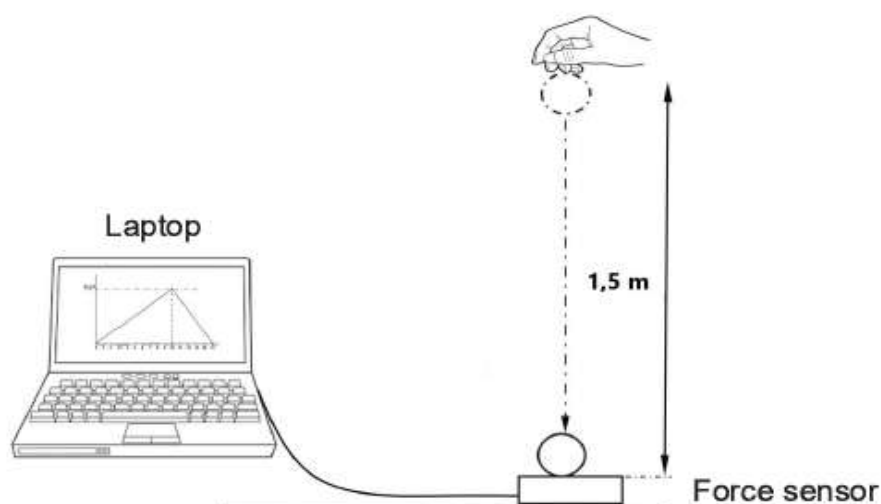
A delivery vehicle of mass 5 000 kg, moving at a velocity of $15 \text{ m}\cdot\text{s}^{-1}$ to the right collides head-on with a car of mass 2 000 kg moving at $20 \text{ m}\cdot\text{s}^{-1}$ in the opposite direction. Immediately after the collision, the car moves at a velocity of $5 \text{ m}\cdot\text{s}^{-1}$ to the right.



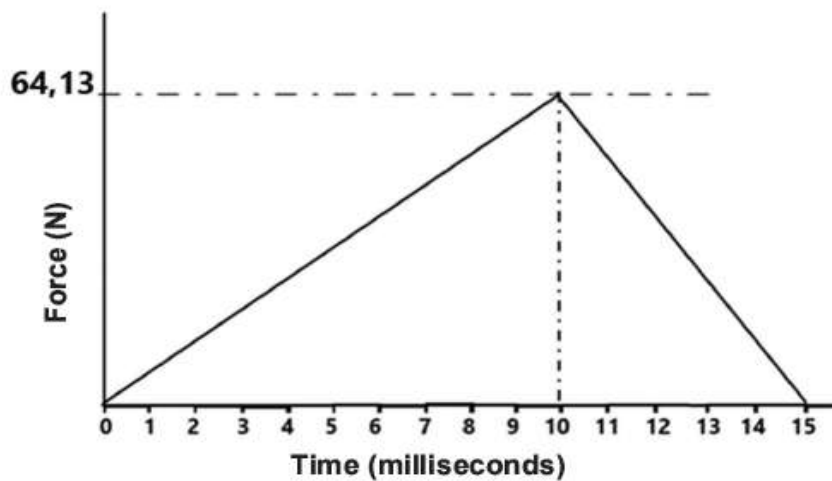
- 4.1 Write down the principle of conservation of linear momentum in words. (2)
 - 4.2 Calculate the magnitude of the velocity of the delivery vehicle immediately after the collision. (4)
 - 4.3 If the collision lasts 0,4 seconds, calculate the force the delivery vehicle exerts on the car during the collision. (4)
- [10]**

ACTIVITY 23 GT23

When a ball hits and bounces off a surface, it exerts a force on that surface. Grade 12 learners investigated how this force varies over time as the ball hits a force sensor and bounces off. A 50 g soft ball was dropped from a height of 1,5 m vertically above a force sensor connected to a laptop as shown on the diagram.



The following graph is obtained from the laptop:



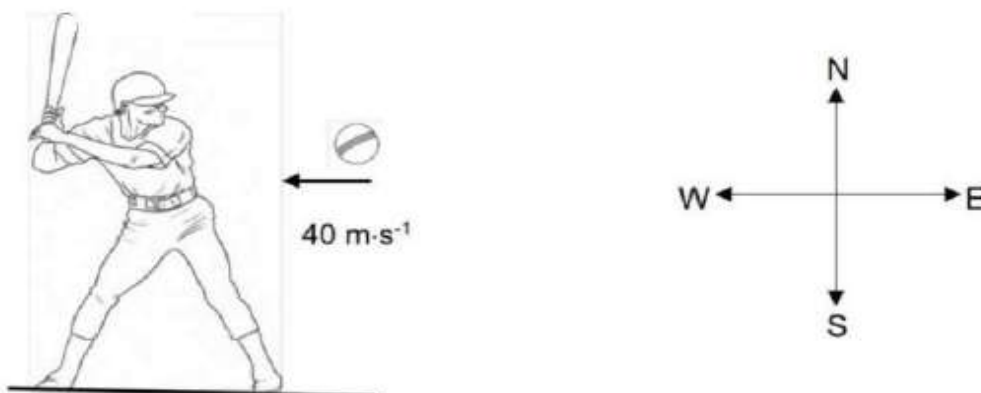
- 4.1 Define the term *impulse*. (2)
- 4.2 Use the information on the graph to determine the magnitude of the impulse as the ball hits and bounces off the force sensor. (2)
- 4.3 State the magnitude and the direction of the change in the momentum of the ball. (2)
- 4.4 If the velocity of the ball just before it hits the force sensor is $5,42 \text{ m}\cdot\text{s}^{-1}$ downwards, calculate the velocity with which the ball will bounce off the sensor. (4)
- 4.5 The ball is now replaced with a hard ball of the same size and mass. Will the force on the force sensor INCREASE, DECREASE OR REMAIN THE SAME? Explain the answer. (3)

[13]

ACTIVITY 24 F523

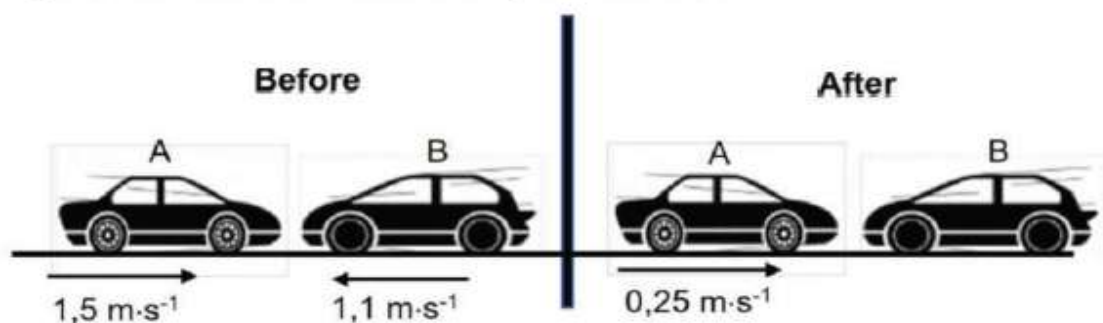
- 4.1 A 400 g ball is approaching a baseball player horizontally in a westerly direction at a speed of $40 \text{ m}\cdot\text{s}^{-1}$ as indicated in the diagram. The baseball player exerts a force of 400 N on the ball in an easterly direction.

The ball is in contact with the bat for 0,1 s.



- 4.1.1 Define *impulse*. (2)
- 4.1.2 Calculate the velocity of the ball immediately after contact with the bat. (4)
- 4.2 When cars are equipped with flexible bumpers, they will bounce off each other during low-speed collisions, thus causing less damage. In one such accident, car A with mass 1 750 kg, travelling to the right at $1,5 \text{ m}\cdot\text{s}^{-1}$, collides with car B of mass 1 450 kg travelling to the left at $1,1 \text{ m}\cdot\text{s}^{-1}$. Measurements show that the speed of car A after the collision is $0,25 \text{ m}\cdot\text{s}^{-1}$ in its original direction.

Ignore the effects of friction during the collision.



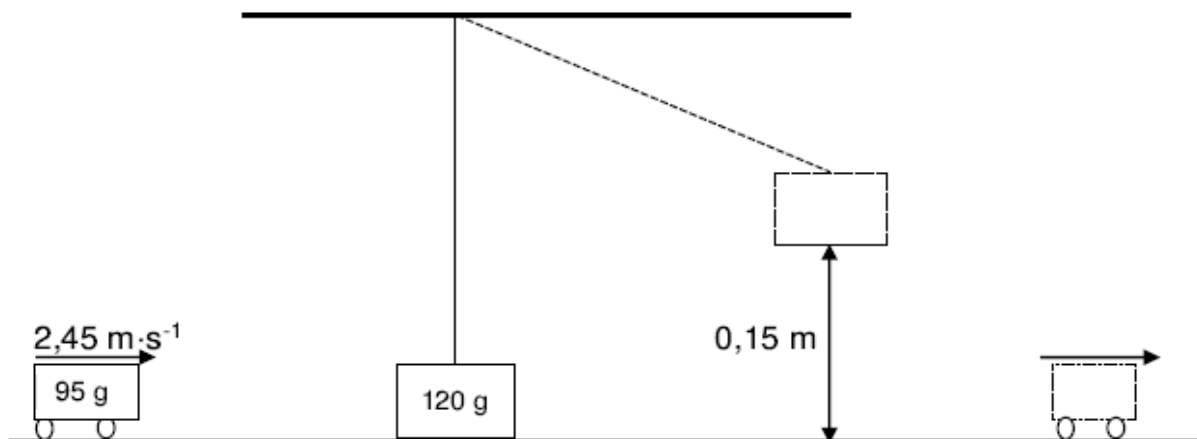
- 4.2.1 Calculate the velocity of car B immediately after the collision. (5)
- 4.2.2 'When cars are equipped with flexible bumpers, they will bounce off each other during low-speed collisions, thus causing less damage.' Explain how flexible bumpers reduce damages during low-speed collisions. (3)

ACTIVITY 25 NWT24

A toy trolley of mass 95 g is moving east at a speed of $2,45 \text{ m} \cdot \text{s}^{-1}$. It collides with a stationary wooden block of mass 120 g, which is suspended with a rope, as shown in the diagram below.

The impact causes the block to move to a maximum height of 0,15 m from its original position, while the trolley continues moving eastwards.

Ignore the effects of friction and air friction.



- 4.1 State the principle of conservation of linear momentum in words. (2)
 - 4.2 Draw a force diagram for the block at a height of 0,15 m above the ground. (2)
 - 4.3 Calculate the speed of the trolley immediately after the collision. (5)
 - 4.4 The contact time between the trolley and the block is 0,08 s.
Calculate the magnitude of the force applied on the trolley by the block. (3)
- [12]**