# TECHNICAL SCIENCE

## MOMENTUM AND IMPULSE

## GRADE 12

basic education
Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

Read to Lead
A Reading Nation is a Leading Nation

2030
NDP

# Foreword

In order to improve learning outcomes the Department of Basic Education conducted research to determine the specific areas that learners struggle with in Grade 12 examinations. The research included a trend analysis by subject experts of learner performance over a period of five years as well as learner examination scripts in order to diagnose deficiencies or misconceptions in particular content areas. In addition, expert teachers were interviewed to determine the best practicesto ensure mastery of thetopic by learners and improve outcomes in terms of quality and quantity.

The results of the research formed the foundation and guiding principles for the development of the booklets. In each identified subject, key content areas were identified for the development of material that will significantly improve learner's conceptual understanding whilst leading to improved performance in the subject.

The booklets are developed as part of a series of booklets, with each bookletfocussing onlyon one specific challenging topic. The selected content is explained in detail and include relevant concepts from Grades 10 - 12 to ensure conceptual understanding.

The main purpose of these booklets is to assist learners to master the content starting from a basic conceptual level of understanding to the more advanced level. The content in each booklets is presented in an easy to understand manner including the use of mind maps, summaries and exercises to support understanding and conceptual progression. These booklets should ideally be used as part of a focussed revision or enrichment program by learners after the topics have been taught in class. The booklets encourage learners to take ownership of their own learning and focus on developing and mastery critical content and skills such as reading and higher order thinking skills.

Teachers are also encouraged to infuse the content into existing lesson preparation to ensure in-depth curriculum coverage of a particular topic. Due to the nature of the booklets covering only one topic, teachers are encouraged to ensure learners access to the booklets in either print or digital form if a particular topic is taught.

# Contents

## 2. HOW TO USE THIS BOOKLET

- This book is intended to guide you through the topics. It is a complimentary publication to the textbooks, worksheets and other learning materials you might have. Your efforts to practice and master the concepts outlined will assist you to develop confidence in the learning and assessments you will do.
- Ensure you understand all the relevant concepts, formulae, etc.
- Do extra research on your own to obtain more information on the topics in this booklet. It is important that you share and discuss your understanding of your findings with your fellow learners.
- Work through the examples given under each topic, master them and try to provide more examples yourself. You must go through examples in your textbooks. At the end of Unit 5, there are exercises for you to do. Work through them on your own and compare your answers with the answers provided in Unit 6.
- When doing calculations, take note of all the information given. It is intended to help you. Read the given information with the intention of understanding what you must do with it. Always look for the action verbs in the instruction, in order to answer correctly. Examples include: determine, explain, discuss, calculate, list, compare.
- If you are given measurements in millimetres (mm), convert these into meters.
- Familiarise yourself with the scientific notations used, e.g. kilo, mega, giga and write them as 10x.
- It is important to show SI units on the final answer. This will earn you a mark.
- At the beginning of each topic section, an extract from the Examination Guidelines is included. You must use this to check what you are expected to master. Revise what you have not mastered and do more exercises.

# 3. STUDY AND EXAMINATION TIPS

**Some tips on how to approach the examinations:**

## 3.1 Tips for Physical Sciences Paper 1

**Format of question papers**

| PAPER | QUESTION TYPE | DURATION | TOTAL |
|---|---|---|---|
| 1 | • 10 Multiple-choice questions – 20 marks<br>• Structured questions – 130 marks | 3 hours | 150 |
| 2 | • 10 Multiple-choice questions – 20 marks<br>• Structured questions – 130 marks | 3 hours | 150 |

Weighting of prescribed content

| P1 CONTENT | | | P2 CONTENT | | |
|---|---|---|---|---|---|
| **Content** | **Marks** | **%** | **Content** | **Marks** | **%** |
| Mechanics | 108 | 72 | Organic molecules | 54 | 36 |
| Electricity and Magnetism | 42 | 28 | Electrochemistry | 42 | 28 |
| | | | Light | 54 | 36 |

**Laws, definitions and principles**

Study and understand the laws, definitions, concepts and principles stated in the examination guidelines. Careful attention must be paid to the key words.

**Using formulae**

- Always use formulae from the formula sheet.
- Common mistakes occur when you change the subject of the formula; thus, it is recommended that you substitute into the given formula and isolate the unknown. However, those of you who are confident with changing the subject of the formula may continue to use this method as it is an efficient method.
- Familiarise yourself with the formula sheet to avoid wasting time during the examination.
- Round off your final answer to a minimum of two decimal places and include the correct unit.

**Answering multiple-choice questions**

Multiple-choice questions (MCQs) ask a learner to recognise a correct answer among a set of options that include 3 or 4 wrong answers (called distracters).

The level of difficulty will vary in MCQs. Resorting to guessing may lead to giving incorrect answers.

There are strategies that can be used to maximise your success in answering MCQs. The best way to improve your chances, of course, is to study carefully before the exam and to make sure that you understand your work, instead of just memorising information.

Here are a few tips to help reduce the possibility of making mistakes or of getting confused by distracters that look similar to the correct answer.

**Step 1**

- Always cover the possible options given with a piece of paper or your hand while you read the stem or body of the question.
- Read carefully and make sure you understand what you are required to do. Rushing through a question may result in misinterpretation.

**Step 2**

Try to anticipate the correct answer before looking at the given options.

**Step 3**

- Uncover the responses and read them. If you see the response you anticipated or one that closely matches your anticipated response, circle/ mark it and then check the others to make sure none of them is a better response. It is important to read all given responses.
- If your anticipated response is not amongst the given ones, or if you are not able to anticipate an answer, read the given options and eliminate those you know are wrong.
- By eliminating wrong options, you will be left with fewer options from which to select your answer. This makes it easier to look for the correct option.

**Step 4**

- Look at the remaining options; compare them for differences and then refer to the stem of the question to find the correct answer.

***If you cannot answer a question in 1 minute, skip it and plan to come back to it later.***

## 3.2 Tips for Momentum and Impulse

- The topic of Momentum & Impulse is assessed in Paper 1.
- Choose a sign convention and indicate it on your answer sheet, in your answer to the question on momentum and impulse.
- Copy the formula as it is written in the data sheet, without attempting to manipulate it.
- Ensure that all values are in SI units, i.e. carry out the necessary conversion.
- Show all substitutions.
- Include the correct unit for the answer.

**Sketching of force and free-body diagram**s

- You must be able to distinguish between a free-body and force diagrams.
- The mark allocation is a guide to the number of forces required in the diagram, e.g. for 4 marks, 4 labelled forces should be drawn.
- Extra forces, leaving out the arrowheads, and arrows that do not touch the dot (object) will result in lost marks, due to negative marking.
- Label the forces correctly.
- **DEFINITION OF TERMS –** know and understand all the definitions and terms

| LAW/CONCEPT/TERM | DEFINITION |
|---|---|
| Momentum | The product of an object's mass and its velocity |
| Newton's Second Law of Motion in terms of momentum | The net (or resultant) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force. |
| Impulse | The product of the net force acting on an object and the time the net force acts on the object. |
| An isolated system (in Physics): | One on which the net external force acting on the system is zero. |
| | |
| The principle of conservation of linear momentum | The total linear momentum of an isolated system remains constant (is conserved) in magnitude and direction. |

# 4. OVERVIEW OF MOMENTUM AND IMPULSE

## MOMENTUM AND IMPULSE

**Momentum (p)** of an object is the product of its mass (***m***) and velocity (***v***).
The mass of the object must be in kilograms (***kg***).
The velocity of the object must be in ($m \cdot s^{-1}$)

Formula: $p = mv$
SI unit : $kg \cdot m \cdot s^{-1}$
Momentum (p) is a vector, thus direction is important.

Momentum of an object depends on its:
1. mass
2. velocity

**Change in momentum** ($\Delta p$) is
- the difference between final momentum (pf) and (pi)
- a vector quantity (direction is important)
- dependent on $\Delta v$

SI unit: $kg \cdot m \cdot s^{-1}$

Formula:

$$\Delta p = p_f - p_i$$
$$\Delta p = m \cdot \Delta v$$
$$\Delta p = m(v_f - v_i)$$

Law of conservation of linear momentum:
The total linear momentum of an isolated system remains constant (is conserved) in magnitude and direction.
$\Sigma p_{before} = \Sigma p_{after}$

**Newton's second law in terms of linear momentum:** the net (resultant) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force.

$$F_{net} = \frac{\Delta p}{\Delta t}, \text{ therefore}$$
$$F_{net}\Delta t = \Delta p$$

**Impulse** is the product of a net force and time ($F_{net}\Delta t$) and is

**Formulae:** $F_{net}\Delta t = \Delta p$
$$F_{net}\Delta t = m(v_f - v_i)$$
Impulse is a vector quantity, direction is important.
**SI units:** $1\ N \cdot s = 1\ kg \cdot m \cdot s^{-1}$

Types of collisions
- Elastic - total kinetic energy is conserved:
  **ΣEki = ΣEkf**
- Inelastic – total kinetic energy is not conserved.
  **ΣEki ≠ ΣEkf**
  Total linear momentum is conserved in both collisions.

# 5. MOMENTUM AND IMPULSE

## 5.1 Momentum

### MOMENTUM

- Define momentum as the product of an object's mass and its velocity.
- Describe linear momentum as a vector quantity with the same direction as the velocity of the object.
- Calculate the momentum of a moving object using p = mv, in the context of technology.

### NEWTON'S SECOND LAW IN TERMS OF MOMENTUM

- State Newton's Second Law of Motion in terms of momentum:
- The net (or resultant) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force.
- Net force is equal to the rate of change in momentum, $F_{net} = \frac{\Delta p}{\Delta t}$.
- Calculate the change in momentum when a resultant force acts on an object and its velocity:
  - increases in the direction of motion, e.g. 2$^{nd}$ stage rocket engine fires
  - decreases, e.g. brakes are applied
  - reverses its direction of motion, e.g. a soccer ball is kicked back in the direction it came from.

### IMPULSE

- Define impulse as the product of the net force acting on an object and the time that the net force acts on the object.
- Impulse is equal to the change in momentum.
- Use the impulse-momentum theorem provided below to calculate: the force exerted; the length of time the force is applied; the change in momentum for a variety of situations involving the motion of an object in one dimension, in the context of technology.
  $F_{net} \Delta t = m \Delta v$,
- Explain how the concept of impulse applies to road safety considerations in everyday life, e.g. airbags, seatbelts, crumple zones and arrestor beds.

### CONSERVATION OF MOMENTUM AND ELASTIC AND INELASTIC COLLISIONS

- Explain what is meant by:
  - An isolated system (in Physics): An isolated system is one in which the net external force acting on the system is zero.
  - Internal and external forces.
- State the principle of conservation of linear momentum: The total linear momentum of an isolated system remains constant (is conserved) in magnitude and direction.
  • Use the conservation of momentum principle to solve problems involving momentum in the context of technology. Restrict problems to two objects moving in one dimension (along a straight line) with the aid of an appropriate sign convention.
- Distinguish between elastic collisions and inelastic collisions by calculation.

## 5.2 IMPULSE AND CHANGE IN MOMENTUM

### Momentum and impulse

- Momentum is the product of an object's mass and its velocity.
- Momentum = mass x velocity

  $p = m\,v$

- Since mass is measured in kg and velocity is measured in $m.s^{-1}$, the S.I unit for momentum is $kg.m.s^{-1}$
- Momentum is a vector quantity, i.e. it has both magnitude and direction.
- There are two types of momentum, viz. angular momentum (i.e. due to the rotation of an object), and linear momentum (movement in a straight line). We are only concerned with **linear momentum.**
- Impulse is the product of the net force acting on an object and the time the net force acts on that object.
- In mathematical terms, it is expressed in symbols as: Impulse = $F_{net}\Delta t$
- **Impulse – Momentum Theorem**: $F_{net}\,\Delta t = \Delta p$

### WORKED EXAMPLES

a) Determine the momentum of a 6 kg object moving at 5 $m.s^{-1}$ to the right.

**Solution**

$p = mv$

$= 6(5)$

$= 30$ $kg.m.s^{-1}$ to the right

b) A car has a momentum of 20 000 $kg\cdot m\cdot s^{-1}$. Calculate the car's new momentum if its velocity is doubled.

**Solution**

$p = mv$

$= m(2v)$

$= 2(mv)$

$= (2)(20\ 000)$

$= 40000\ kg.m.s^{-1}$

The momentum will double and will be equal to 40 000 $kg\cdot m\cdot s^{-1}$ in the same direction as before.

(c) Calculate the velocity of the car if its momentum is 60 000 $kg \cdot m \cdot s^{-1}$ and the mass is 2 000 kg?

**Solution**

$p = mv$

$60\,000 = 2\,000\, v$

$v = 30\ m \cdot s^{-1}$ in the same direction as the momentum.

## 5.3 Newton's Second Law in terms of momentum

- The net (or resultant) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force, $F_{net}\, \Delta t = \Delta p$
- The momentum of an object changes with its velocity.
- Change in momentum = mass (final velocity – initial velocity)

$$\begin{aligned} p &= p_{final} - p_{initial} \\ &= mv_f - mv_i \\ &= m\,(v_f - v_i) \end{aligned}$$

**Example**

A 500 g soccer ball is kicked at 12 $m \cdot s^{-1}$ towards a wall. It rebounds off the wall at 2 $m \cdot s^{-1}$. Calculate the change in momentum.

**Solution**

Choose initial direction as the positive.

$p_i = mv_i = 0{,}5 \times 12 = 6\ kg \cdot m \cdot s^{-1}$

$p_f = mv_f = 0{,}5 \times -2 = -1\ kg \cdot m \cdot s^{-1}$

$\Delta p = p_f - p_i = -1 - 6 = -7\ kg \cdot m \cdot s^{-1}$

$\Delta p = 7\ kg \cdot m \cdot s^{-1}$ away from the wall

## 5.4 IMPULSE

**Example 1**

A golf ball with a mass of 0, 1 kg is driven from the tee.

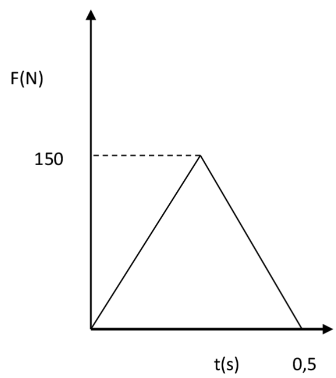

The golf ball experiences a force of 1000 N while in contact with the golf club and moves away from the golf club at 30 m·s$^{-1}$. Calculate the time during which the golf club was in contact with the ball.

$$F_{net}\,\Delta t = \Delta p$$
$$1000(\Delta t) = (30 - 0)$$
$$t = 3 \times 10^{-3}\ \text{s}$$

**Example 2**

The following graph shows the force exerted on a hockey ball over time. The hockey ball is initially stationary and has a mass of 150 g.

Calculate the magnitude of the impulse of the hockey ball.




**Solution**

$$F_{net}\Delta t = \text{impulse} = \text{area under graph}$$
$$= \frac{1}{2}\ \text{base x height}$$
$$= \frac{1}{2}\ (0{,}5\ \text{x}\ 150)$$
$$= 37{,}5\ \ \text{N.s}$$

## TEST YOUR KNOWLEDGE

**Question 1**

A 12 kg object speeds up from an initial velocity of 10 $m \cdot s^{-1}$ north to a final velocity of 15 $m.s^{-1}$ north. Calculate the change in momentum.

**Question 2**

A 20 kg object slows down from an initial velocity of 40 $m \cdot s^{-1}$ west to a final velocity of 5 $m \cdot s^{-1}$ west. Calculate the change in momentum.

**Question 3**

A car with a mass of 1 200 kg is travelling at 72 $km.h^{-1}$ when the driver sees a dog running across the street. He applies the brakes and 10 seconds later the car is moving at 18 $km.h^{-1}$.

I. Calculate the initial momentum of the car.

II. Calculate the final momentum of the car.

III. Calculate the change in momentum of the car.

IV. Calculate the net force applied by the brakes of the car.

### 5.5 THE PRINCIPLE OF CONSERVATION OF LINEAR MOMENTUM

- The total linear momentum of an isolated system remains constant (is conserved) in magnitude and direction.
- An isolated system is one in which the net external force acting on the system is zero.

## COLLISIONS

- There are a number of possible types of collision that can take place between two objects moving along the same line (one dimension), e.g.:
  - one moving object collides with a stationary object
  - two objects move towards each other and collide
  - two objects move in the same direction and collide
  - one unit separates into parts (explosion) e.g. an exploding bomb:

**Possible results from collisions:**

- both objects collide and stop
- one object moves and the other object stops moving
- both objects move but are not joined
- two objects join together and move off at the same speed

Elastic and Inelastic Collisions:

- In an elastic collision, total kinetic energy and total linear momentum are conserved.
- In an inelastic collision, total linear momentum is conserved, but not total kinetic energy.
- The conservation of kinetic energy is determined by calculating the total kinetic energy of all parts of the closed system, before the collision, and then comparing that to the total kinetic energy of all the parts of the closed system after the collision.

## WORKED EXAMPLES

A tennis ball with a mass of 0,06 kg is thrown horizontally towards a wall. It hits the wall at 5 m·s $^{-1}$, and bounces back at 3 m·s $^{-1}$.

Calculate:

i. The initial momentum of the tennis ball.

ii. The final momentum of the tennis ball.

iii. The change in momentum of the tennis ball.

**Solution**

Take the direction to the right as being positive.

i. Initial momentum: $p_i = mv_i$

$= (0,06)\ (5)$

$= +0,3$ kg·m· s $^{-1}$

$= 0,3$ kg·m· s $^{-1}$ to the right

ii. Final momentum: $p_f = mv_f$

$= (0.06)(-3)$

$= -0,18$ kg·m·s $^{-1}$

$= 0,18$ kg·m·s $^{-1}$ to the left

iii. Change in momentum $= p_f - p_i$

$= (-0,18 – 0.3)$

$= -0,48$ kg·m·s $^{-1}$

$= 0,48$ kg·m·s $^{-1}$ to the left

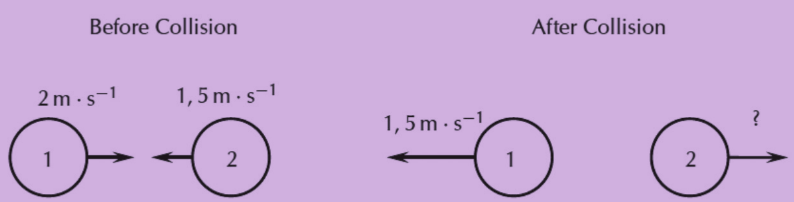
# TEST YOUR KNOWLEDGE

### Question 1

A 35 kg girl is standing near and to the left of a 43 kg boy on the frictionless surface of a frozen pond. The boy throws a 0, 75 kg ice ball to the girl with a horizontal speed of 6.2 $m \cdot s^{-1}$. What are the velocities of the boy and the girl immediately after the girl catches the ice ball?

### Question 2

Two billiard balls (ball 1 and ball 2),each with a mass of 150 g, collide head-on, as shown in the diagram below. Ball 1 was travelling at a speed of 2 $m \cdot s^{-1}$ and ball 2 was travelling at a speed of 1, 5 $m \cdot s^{-1}$. After the collision, ball 1 travels away from ball 2 at a speed of 1, 5 $m \cdot s^{-1}$.



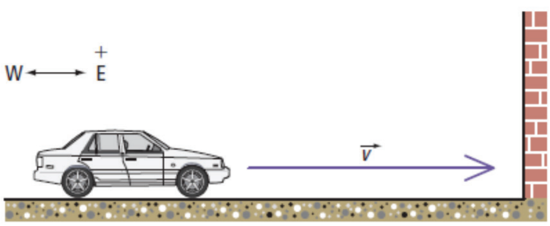

I. Calculate the velocity of ball 2 after the collision.

II. Prove that the collision was elastic. Show by means of calculations.

# EXERCISES

### QUESTION 1

1.1 To improve the safety of motorists, modern cars are built so that the front-end crumples upon impact. A 1200 kg car is travelling at a constant velocity of 8 $m \cdot s^{-1}$. It hits a wall and comes to a complete stop in 0, 25 s.

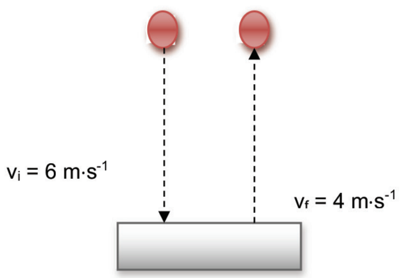



I. Calculate the change in momentum.

II. Calculate the average net force exerted on the car.

III. For the same impulse, determine the average net force exerted on the car, if it had a rigid bumper and frame that stopped the car in 0,040 s.

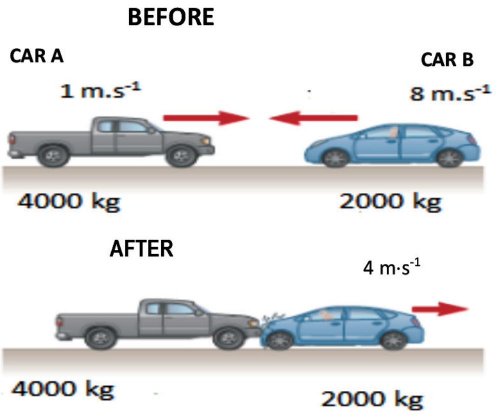
1.2 A rubber ball with a mass of 800 g is dropped and hits the floor with an initial downward velocity of 6 m·s$^{-1}$. The ball bounces back with a final velocity of 4 m· s$^{-1}$.




Calculate the change in momentum of the ball.

## QUESTION 2

Car A that has a mass of 2000 kg is moving at 8 m·s$^{-1}$ to the west. It collides with Car B that has a mass of 4000 kg moving at 1 m·s$^{-1}$ to the east.




2.1 State the principle of conservation of linear momentum.

2.2 Calculate the change in momentum of the 2000 kg car.

2.3 Calculate the velocity of car B, if car A moves with a velocity of 4 m.s$^{-1}$ After the collision.

## QUESTION 3

A cannon has a mass of 1 250 kg. It fires a cannon-ball during a routine exercise. The cannon is 1000 times heavier than the cannon ball. The cannon ball leaves the barrel at a horizontal velocity of 70 $m.s^{-1}$.


The cannon comes to **rest 1** second after the cannon-ball was fired.

3.1 Define, in words, the term impulse.

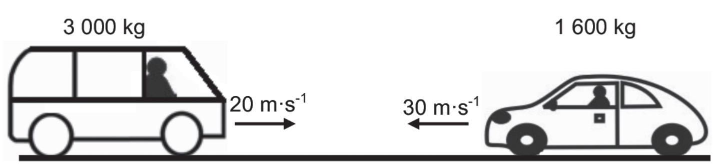
3.2 Calculate the following:

3.2.1 maximum velocity with which the cannon moves backwards;

3.2.2 magnitude of the average net force that causes the cannon to come to rest.

## QUESTION 4

Collisions happen daily on the roads in our country. In one of these collisions, a car with a mass of 1 600 kg is travelling at a speed of 30 $m \cdot s^{-1}$ to the left. It collides head-on with a minibus that has a mass of 3 000 kg, which is travelling at 20 $m \cdot s^{-1}$ to the right. The two vehicles move together as a unit in a straight line after the collision.

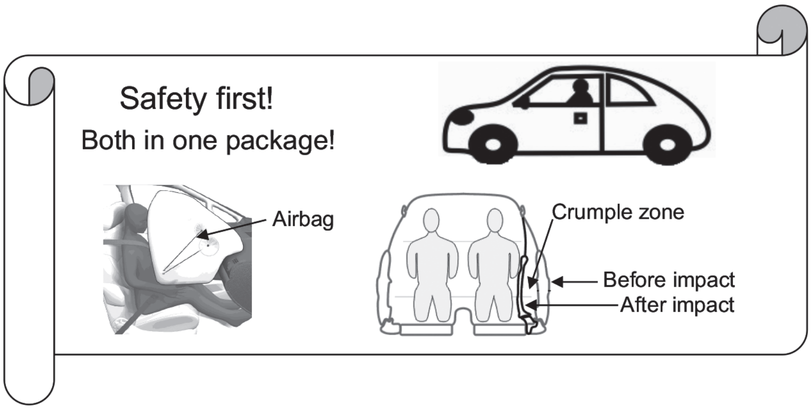



4.1 Calculate the velocity of the two vehicles after the collision.

4.2 Do the necessary calculations to show that the collision was inelastic.

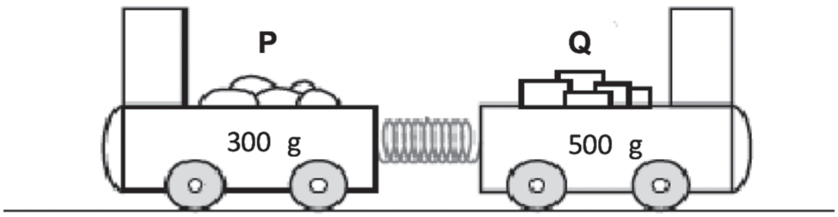
4.3 The billboard below advertises a car from a certain manufacturer.

Use your knowledge of momentum and impulse to justify how the safety features mentioned in the advertisement contribute to the safety of the passengers.




## QUESTION 5

The diagram below shows two trolleys (**P** and **Q**) that are held together by means of a compressed spring on a flat, frictionless horizontal track. The mass of **P** and **Q** is 300 g and 500 g, respectively.




When the trolleys are released, it takes 0,5 s for the spring to unwind to its natural length. **Trolley Q** then moves to the right at 2 $m \cdot s^{-1}$.

5.1 State the *principle of conservation of linear momentum* in words.

5.2 Calculate the following:

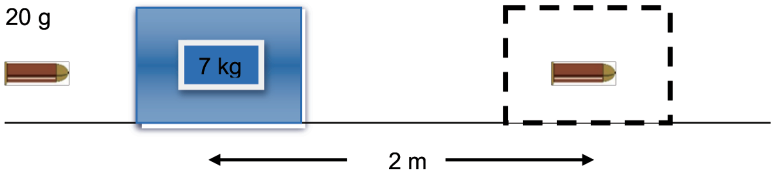
5.2.1 velocity of trolley **P** after the trolleys are released;

5.2.2 magnitude of the average force exerted by the spring on trolley **Q**.

5.3 Is this an elastic or inelastic collision?

## QUESTION 6

The diagram below shows a bullet with a mass of 20 g that is travelling horizontally. The bullet strikes a stationary 7 kg block and becomes embedded in it. The bullet and the block travel on a rough horizontal surface for a distance of 2 m before coming to a stop.



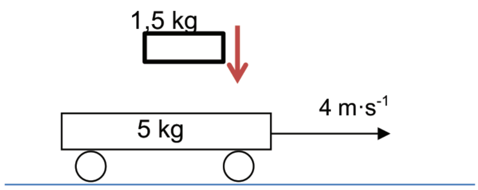

At the moment of impact, the bullet and the block begin to move with a velocity of 2,39 $m \cdot s^{-1}$.

6.1 State the *Principle of Conservation of Linear Momentum* in words.

6.2 Calculate the magnitude of the velocity with which the bullet hits the block.

## QUESTION 7

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




7.1 State, in words, the *Law of Conservation of Linear Momentum*.

7.2 State the condition for an elastic collision.

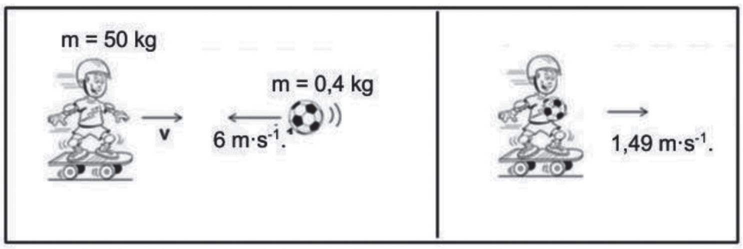
7.3 Calculate the change in momentum of the 5 kg trolley.

## QUESTION 8

A girl with a mass of 65 kg is driving a 535 kg snowmobile at a constant velocity of 11,5 m·s$^{-1}$ [60$^{o}$ E of N]. Calculate the momentum of the girl-snowmobile system.

## QUESTION 9

A boy on a skateboard moves to the right at constant velocity. The joint mass of the boy and skateboard is 50 kg. He catches a ball with of mass 0,4 kg while the ball is travelling horizontally to the left at a speed of 6 m·s$^{-1}$. After the boy catches the ball, they both move to the right at 1,49 m·s$^{-1}$.




Before boy catches ball After boy catches ball

9. 1 Define the term *impulse.*

9.2 Calculate the magnitude of the average force that the boy exerts on the ball when he catches it, if he and the ball exert a force on each other for a period of 0,1 s.

9.3 Write down the *Principle of Conservation of Linear Momentum* in words.

9.4 Calculate the magnitude of the velocity (**v**) of the boy before he catches the ball.

9.5 Prove that this is an inelastic collision and show all the necessary calculations.

# 6. CHECK YOUR ANSWERS

## TEST YOUR KNOWLEDGE SOLUTIONS

## MOMENTUM AND IMPULSE

### Question 1

Take north as positive.

$\Delta p = m(v_f - v_i)$

$= 12(15-10)$

$= 60$ kg.m.s$^{-1}$, north

### Question 2

Take west as positive.

$\Delta p = m(v_f - v_i)$

$= 20(5-40)$

$= -700$ kg.m.s$^{-1}$

$=700$ kg.m.s$^{-1}$ west

### Question 3

I. $p = mv$

$= 1200(20)$

$= 24000$ kg.m.s$^{-1}$ forward

II. $p = mv$

$=1200(5)$

$=6000$ kg.m.s$^{-1}$ forward

III. $\Delta p = m(v_f - v_i)$

$=1200(6000-24000)$

$= 2,16 \times 10^7$ kg.m.s$^{-1}$ in the opposite direction

IV. $F_{net}\Delta t = m\Delta v$

$F_{net}(10) = -2,16x\ 10^7$

$F_{net} = 2,16 \text{ X } 10^6$ N in the opposite direction

## CONSERVATION OF MOMENTUM

### Question 1

$m_B\mathbf{v}_B \quad + \quad m_P\,\mathbf{v}_P = m_B v_B \quad + \quad m_P\mathbf{v}_P$

$0 + 0 = 43\,(v_B) + 0{,}75(6.2)$

$v_B = 0{,}108\ m.s^{-1}$

$m_G\mathbf{v}_G \quad + \quad m_P\mathbf{v}_P \quad = v(m_G \ + m_P)$

$35(0) + 0{,}75(-6{,}2) = v(35{,}75)$

$v = -\ 0{,}13\ m.s^{-1}$

$v = 0,\ 13\ m.s^{-1}$ to the left

### Question 2

I. $\Sigma\mathbf{p}_{before} \quad = \quad \Sigma\mathbf{p}_{after}$

$m_1v_{1i} + m_2v_{2i} = m_2v_{1f} + m_2v_{2f}$

$(0{,}15)(2)+(0{,}15)(-1{,}5) = (0{,}15)(-1{,}5)+0{,}15v_{f2}$

$0{,}3-0{,}225 = -0{,}225+0{,}15_{v2}$

$v_{f2} = 3\ m\cdot s^{-1}$ to the right.

II. $\Sigma E_{K(before)} = \dfrac{m_1V_{i1}^2}{2} + \dfrac{m_2v_{i2}^2}{2} = \dfrac{(0{,}15)(2)^2}{2} + \dfrac{(0{,}15)(-1{,}5)^2}{2} = 0{,}469\ J$

$\Sigma E_{K(after)} = \dfrac{m_1V_{f1}^2}{2} + \dfrac{m_2v_{f2}^2}{2} = \dfrac{(0{,}15)(-1{,}5)^2}{2} + \dfrac{(0{,}15)(2)^2}{2} = 0{,}469\ J$

So, $\Sigma E_{K(before)} = \Sigma E_{K(after)}$

$\therefore$ Collision is elastic.

## SOLUTIONS TO EXERCISES

## QUESTION 1

1.1

I. $\Delta p = m(v_f - v_i)$

$= (1200)(0 - (8)$

$= (1200)(8.0)$

$= 9.6 \times 10^3$ kg·m·s$^{-1}$ (west)

II. $F_{net}\,\Delta t = -9{,}6 \times 10^3$ N·s

$$F_{net} = \frac{-9{,}6 \text{ X } 10^3}{\Delta t}$$

$$F_{net} = \frac{-9{,}6 \text{ X } 10^3}{0{,}25}$$

$= -3{,}8 \text{ x } 10^4$ N

$= 3 \text{ X } 10^4$ N West

III. $$F_{net} = \frac{-9{,}6 \text{ X } 10^3}{\Delta t}$$

$$F_{net} = \frac{-9{,}6 \text{ X } 10^3}{0{,}040}$$

$= -2{,}4 \text{ x } 10^5$

$= 2{,}4 \text{ x } 10^5$ N West

1.2 $\Delta \mathbf{p} = m(\mathbf{v}_f - v_i)$

$= 0{,}8\,(-4 - 6)$

$= 8$ kg·m·s$^{-1}$ upwards

## QUESTION 2

2.1 The total linear momentum of an isolated system remains constant in magnitude and direction.

2.2 $\Delta \boldsymbol{p} = m\,(\boldsymbol{v}_f - v_i)$ (taking east as positive)

$= 2000[4 - (-8)]$

$= 24000$ kg.m.s$^{-1}$ east

2.3 $\Sigma p_i = \Sigma p_f$

$m_1\mathbf{v}_{i1} + m_2\,\mathbf{v}_{i\,2} = m_1 v_{f1} + m_2\,v_{f2}$

$(4000)(1) + 2000(-8) = 4000v_f + (2000)\,(4)$

$v_f = -5$ m.s$^{-1}$

$v_f = 5$ m.s$^{-1}$ west

## QUESTION 3

3.1 Impulse is the product of the resultant/ net force acting on an object and the length of time that the resultant/ net force acts on the object.

3.2

3.2.1

**OPTION 1**

**Take the direction towards the left as positive.**

$\Sigma p_i = \Sigma p_f$

$0 = mv_{cannon} + mv_{ball}$

$0 = (1250)v + 1,25\,(-80)$

$v = 100 / 1250 = 0,084\ m.s^{-1}$, left

**OPTION 2**

**Take the direction towards the right as positive.**

$\Sigma p_i = \Sigma p_f$

$0 = mv_{cannon} + mv_{ball}$

$0 = (1250)v + 1,25\,(80)$

$v = 100 \div 1250 = -0,08\ m.s^{-1}$

$v = 0,084\ m.s^{-1}$, left

3.2.2

**Take the direction towards the left as positive.**

$F_{net}\Delta t = m\Delta v = mv_f - mv_i$

$F_{net}(1) = 1250\,(0 - (-0,084))$

$F_{net} = 105\ N$

OR

$v_f = v_i + a\Delta t$

$0 = -0,084 + a(1)$

$a = 0,084\ m.s^{-2}$

$F_{net} = ma$

$= (1250)(0,084)$

$= 105\ N$ to the right

## QUESTION 4

4.1 Consider the motion to the right as positive.

$$\Sigma p_i = \Sigma p_f$$

$$m_1 v_{i1} + m_2 v_{i2} = (m_1 + m_2)v_f$$

$$(1\,600)(-30) + (3\,000)(20) = (1\,600 + 3\,000)\,v_f$$

$$-48\,000 + 60\,000 = (4\,600)v_f$$

$$v_f = 2{,}6 \text{ m·s}^{-1} \text{ to the right}$$

4.2

**Before collision:**

$$\Sigma E_k = \frac{1}{2} m_1 V_{i1}^2 + \frac{1}{2} m_2 V_{i2}^2 = \frac{1}{2}(1\,600)(-30)^2 + \frac{1}{2}(3\,000)(20)^2$$

$$= 720\,000 + 600\,000$$

$$= 1{,}32 \times 10^6 \text{ J}$$

**After collision:**

$$\Sigma E_k = \frac{1}{2} m_1 V_{f1}^2 + \frac{1}{2} m_2 V_{f2}^2 = \frac{1}{2}(1\,600 + 3\,000)(2{,}6)^2$$

$$= 15548 \text{ J}$$

$\Sigma E_k$ before collision is not equal to $\Sigma E_k$ after collision; therefore, the collision is inelastic.

4.3 During a collision, the crumple zone / airbag **increases the time** during which momentum changes. So, according to the equation …

$F_{net} = \frac{\Delta p}{\Delta t}$, the **force during impact will decrease.**

## QUESTION 5

5.1 The total linear momentum of an isolated system remains constant in magnitude and direction.

5.2.1

$$\sum \mathbf{p_i} = \sum \mathbf{p_f}$$

$$m_1 v1_i + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

$$(m_1 + m_2)v_i = m_1 v_{1f} + m_2 v_{2f}$$

$$0 = (0{,}3)v1_f + 0{,}5\,(2)$$

$$v_{1f} = -3{,}33 \text{ m·s}^{-1}$$

$$= 3{,}33 \text{ m·s}^{-1} \text{ to the left}$$

5.2.2

**OPTION 1**

$m(v_f - v_i) = F_{net}\Delta t$

$0,5(2 - 0) = F_{net}\,(0,5)$

$F_{net} = 2$ N to the right

**OPTION 2**

$m(v_f - v_i) = F_{net}\Delta t$

$0,3(-3,33 - 0) = F_{net}\,(0,5)$

$F_{net} = -2$ N

$F_{net} = 2$ N to the right

5.3 Inelastic

## QUESTION 6

6.1 The total linear momentum of an (isolated) closed system remains constant in magnitude and direction.

6.2

$$\Sigma \mathbf{p}_{before} = \Sigma \mathbf{p}_{after}$$

$$m_1\mathbf{v}_{i1} + m_2\mathbf{v}_{I2} = (m_1 + m_2)\mathbf{v}_f$$

$$(0,02)\mathbf{v}_{i1} + (7)(0) = (7,02)(2,39)$$

$$\mathbf{v}_{i1} = 838,89 \text{ m.s}^{-1}$$

## QUESTION 7

7.1 The total linear momentum of an isolated system remains constant (is conserved) in magnitude and direction.

7.2 The total kinetic energy remains constant.

OR

The total kinetic energy before the collision equals the total kinetic energy after the collision.

7.3 Choose the direction to the right as positive.

$$\Sigma \mathbf{p}_{before} = \Sigma \mathbf{p}_{after}$$

$$m_1 \boldsymbol{v}_{i1} + m_2 \boldsymbol{v}_{i2} = (m1 + m_2)\boldsymbol{v}_f$$

$$(5)(4) + (1,5)(0) = (6,5)\boldsymbol{v}_f$$

$$\boldsymbol{v}_f = 3,077 \text{ m}\bullet\text{s}^{-1}$$

$$\Delta \boldsymbol{p} = m(\boldsymbol{v}_f - v_i)$$

$$= 5(3,077 - 4)$$

$$= -4,62 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1}$$

$$= 4,62 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1}\text{, west}$$

## QUESTION 8

$6.90 \times 10^3$ kgm·s$^{-1}$ [60$^o$ E of N]

## QUESTION 9

9.1 The product of the net force and the time that the net force acts on an object.

9.2 **Take the motion to the right as positive.**

$$F_{net}\Delta t = m\Delta v = m(v_f - v_i)$$

$$F_{net}(0,1) = 0,4(1,49 - (-6))$$

$$F_{net} = 29,96 \text{ N}$$

9.3 The total linear momentum of a closed system remains constant (is conserved).

9.4 Take the motion to the right as positive.

$$\Sigma \boldsymbol{p}_{before} = \Sigma \boldsymbol{p}_{after}$$

$$m_1v_{1i} + m_2v_{i2} = (m_1 + m_2)v$$

$$50v_{i1} + (0,4)(-6) = 50,4(1,49)$$

$$v_{i1} = 1,55 \text{ m·s}^{-1}\text{, to the right}$$

9.5 Total kinetic energy before collision:

$$\Sigma E_{k\ before} = \frac{1}{2} m_1v_{i1}^2 + \frac{1}{2} m_2v_{i2}^2$$
$$= (0,5)(50)(1,55)^2 + (0,5)(0,4)(-6)^2$$
$$= 67,26 \text{ J}$$

Total kinetic energy after collision:

$$\Sigma E_{k\ after} = \frac{1}{2} m_1v_{f1}^2 + \frac{1}{2} m_2v_{f2}^2$$
$$= \frac{1}{2}(m_1 + m_2)v^2$$
$$= (0,5)(50,4)(1,49)^2$$
$$= 55,95 \text{ J}$$

$$\Sigma E_{k\ before} \neq \Sigma E_{k\ after}$$

∴ inelastic collision

## 7. MESSAGE TO GRADE 12 LEARNERS FROM THE WRITERS

To be successful in life, you need to go the extra mile, make sure you study, and work hard. I would like to encourage you by referring to Dr John M Tibane who, in his book entitled *Turbo Think,* makes the following statements:

"Always do more than is required of you".

"The number one reason why most people are not wealthy is that they have not decided to be wealthy".

To be successful, you need to decide to be successful and do more than is required of you in order to expedite your success.

## 8. THANK YOU AND ACKNOWLEDGEMENTS

The Technical Sciences Revision Booklet on Momentum was developed by Ms Lerato Mphachoe, Ms Balungile Manqele (lead writer), Mr Nathi Ndlovu (lead writer), Mr Chele N Lenkoe and Mr Themba Ncube (Subject Specialists, PED). Special acknowledgement must be made of Ms JSK Maharaj (Veena), the DBE curriculum specialist who co-ordinated and finalised the process, in addition to her contributing to the development of the booklet.

These officials contributed their knowledge and experience, and in some cases unpublished work, which they have gathered over the years, to the development of this resource. The Department of Basic Education (DBE) gratefully acknowledges these officials for giving up their valuable time to develop this resource for the children of our country.

Administrative and logistical support was provided by Mr Esrom Fourie. This official was instrumental in the smooth and efficient management of the logistical processes involved in this project.

# TECHNICAL SCIENCE

## MOMENTUM AND IMPULSE

**GRADE 12**

Department of Basic Education
222 Struben Street, Pretoria, 0001
Private Bag X895, Pretoria, 0001, South Africa
Tel: (012) 357 3000 Fax: (012) 323 0601

Hotline: 0800 202 933

**website**
www.education.gov.za

**facebook**
www.facebook.com/BasicEd

**twitter**
www.twitter.com/dbe_sa

**ISBN NO. 978-1-4315-3306-0**