GRADE 12

Technical Sciences

SELF STUDY GUIDE BOOK 1 | PAPER 1

KNOWLEDGE AREA MECHANICS:

1. NEWTON'S LAWS OF MOTION

2. MOMENTUM

3. WORK, ENERGY AND POWER

4. ELASTICITY

basic education
Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

Second Chance
Matric Support Programme

2030 NDP

NATIONAL EDUCATION COLLABORATION TRUST

ETDP SETA

WOZA MATRICS 2021 CATCH UP

STAY SAFE
PROTECT SOUTH AFRICA
TOGETHER WE CAN BEAT THE CORONAVIRUS

INTRODUCTION

The declaration of COVID-19 as a global pandemic by the World Health Organisation led to the disruption of effective teaching and learning in many schools in South Africa. The majority of learners in various grades spent less time in class due to the phased-in approach and rotational/ alternate attendance system that was implemented by various provinces. Consequently, the majority of schools were not able to complete all the relevant content designed for specific grades in accordance with the Curriculum and Assessment Policy Statements in most subjects.

As part of mitigating against the impact of COVID-19 on the current Grade 12, the Department of Basic Education (DBE) worked in collaboration with subject specialists from various Provincial Education Departments (PEDs) developed this Self-Study Guide. The Study Guide covers those topics, skills and concepts that are located in Grade 12, that are critical to lay the foundation for Grade 12. The main aim is to close the pre-existing content gaps in order to strengthen the mastery of subject knowledge in Grade 12. More importantly, the Study Guide will engender the attitudes in the learners to learning independently while mastering the core cross-cutting concepts.

About the Study Guide

To the learner

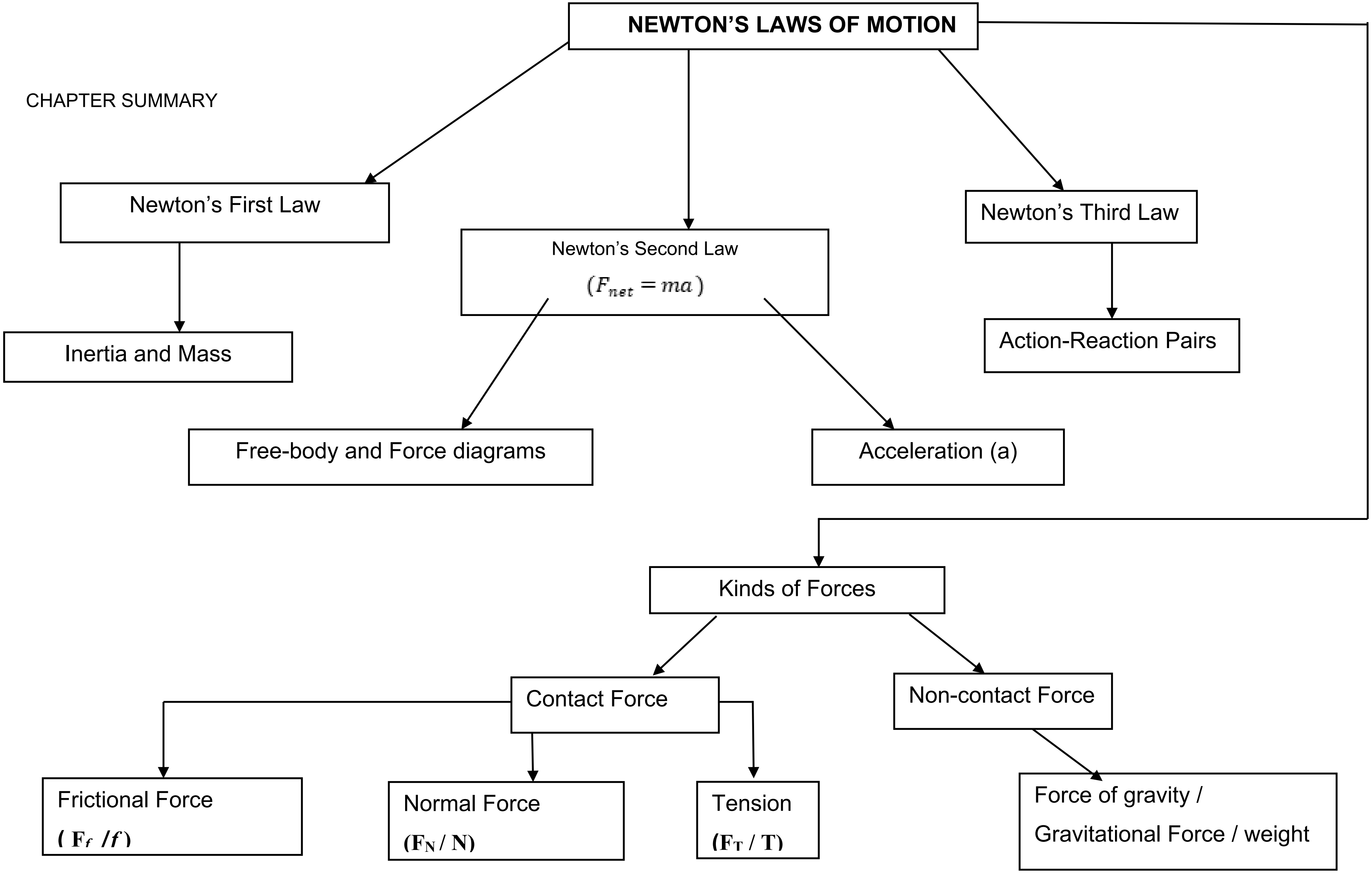
- This document was developed to assist grade 12 learner who are studying remotely (at home).
- This document forms part of the series to be distributed Department of Education Grade 12 learners who are currently taking Technical Sciences as one of their subjects.
- The document deals with one of the knowledge area of the subject which is Mechanics.
- The subtopics are: Newton's law, Momentum, Work, Energy and Power as well as Elasticity.

What to find in this document?

- Short notes with illustrations (images, pictures, diagrams).
- Definitions of terms
- Worked out examples – some of the examples are taken directly from previous formal assessment tasks (Common Assessment tasks) from different Provinces.
- Solutions with brief notes or explanations of what to do and how to obtain a correct answer.

1. NEWTON'S LAWS OF MOTION

CHAPTER SUMMARY



Newton's Laws of Motion

To understand this section of work: You must remember the following work done in **Grade 10 & 11**

1. FORCES (Grade 10 work)

Force is a push or pull (action exerted on an object).

- is a vector quantity (it has magnitude and direction).
- is measured in Newton **(N).**

1.1 Two types of forces

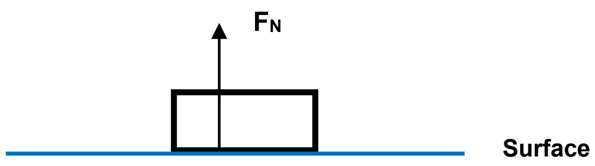
- **Contact forces** - the interacting objects must physically touch one another in order for them to exist.
- **Non-contact forces** - the forces work over a distance without the objects physically touching one another.

Examples of contact forces and non–contact forces

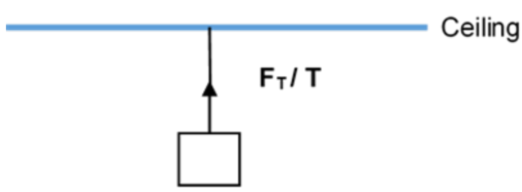
Non-contact forces	Contact Forces
• Gravitational force **(w/F_g)**	• Applied force **(F_A)**
• Electrostatic force	• Tension force **(T or F_T)**
• Magnetic force	• Friction **(F_f, f_s f_k)**
	• Normal force **(F_N or N)**

1.2 DIFFERENT KINDS OF FORCES

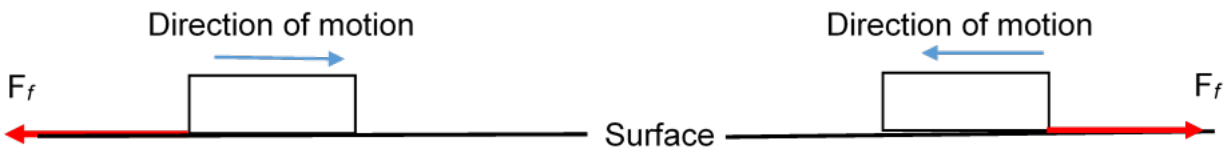
- **NORMAL FORCE (N or F_N)**: is the perpendicular force exerted by a surface on an object that lies on that surface.



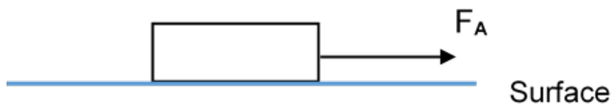
- **TENSION (T or F_T)**: is a force acting on a string or rope.



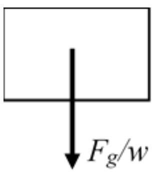
- **FRICTIONAL FORCE (*f* or F_f)** = is the force that opposes the motion of an object and acts parallel to the surface.



- **APPLIED FORCE (F or F_A)**: is a force exerted by one object on the other object.



- **FORCE OF GRAVITY/GRAVITATIONAL FORCE/WEIGHT (F_g)**: is the force of attraction exerted by the earth on an object. It always acts vertically downwards.



- The **gravitational force** / **weight** can be calculated using: $F_g = mg$ or $w = mg$ where '***m'*** is the mass (kg) and '**g**' is gravitational acceleration ($m \cdot s^{-2}$).
- **Resultant or net force (F_{net})** = is the sum of two or more forces acting on an object/ is a single force (vector) which can produce the same effect as two or more forces (vectors) acting together.

TYPES OF FRICTIONAL FORCES (Grade 11 Work)

Static (Limiting)Frictional	Kinetic (Dynamic) Frictional Force
• acts between the two surfaces when the object is stationary	• acts between the two surfaces when the object is moving.
• is given by: $f_s = \mu_s F_N$	• is given by: $f_k = \mu_k F_N$
where:	**where:**
f_s = Static friction (in Newton- **N**)	f_k = kinetic friction (in Newton- **N**)
μ_s = coefficient of static friction (**Has No units**)	μ_k = coefficient of friction **(Has No units)**
F_N = Normal force (in Newton- **N**)	F_N = Normal force (in Newton- **N**)

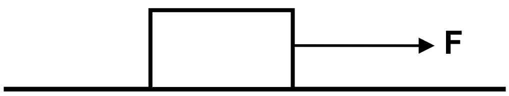
2 FORCE AND FREE-BODY DIAGRAMS

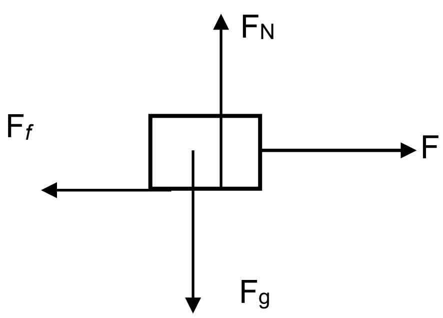
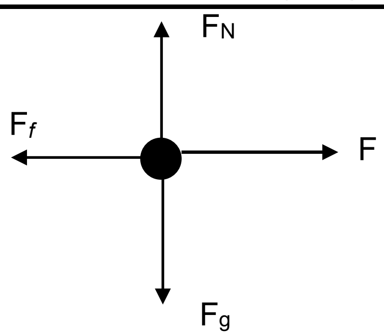
- These are diagrams that are used to represent forces acting on object. We use arrows to represent the forces.

Tips on drawing free-body and Force diagrams

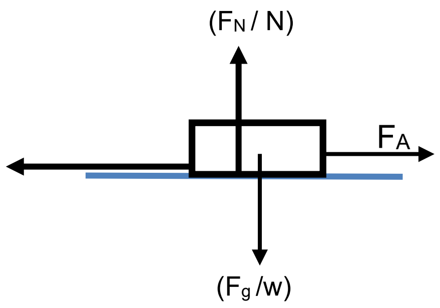
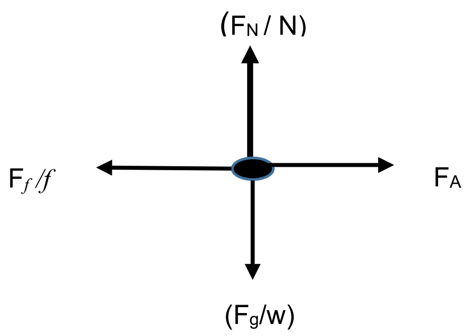
- Determine whether the object is moving (Vertical or horizontal) or not moving (stationary).
    - If stationary on a rough surface, it will experience static friction.
    - If moving on a rough surface, it will experience kinetic friction.
    - On smooth (frictionless) surfaces there is no friction.
- Determine the number of forces acting on the object based on the given scenario.
- The marks allocated for the question determines the number of actual forces acting on the object.

NB: If a question is allocated 4 marks, there are four forces acting on the object.

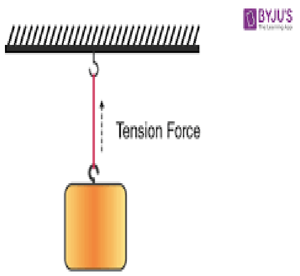
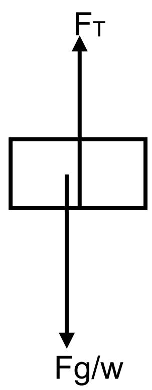
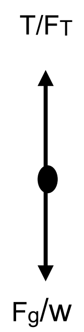
<table>
<tr><th colspan="2">Properties</th></tr>
<tr><th>Force diagram</th><th>Free-body diagram</th></tr>
<tr><td>• We use a box to represent the object.
• F_g is drawn from the centre of the box and points vertically downwards.</td><td>• We use a dot to represent the object.
• The forces start from the dot and point away from it.</td></tr>
<tr><th colspan="2">Worked example No:1</th></tr>
<tr><td colspan="2">An object is pulled by a constant force F on a horizontal rough surface to the right.


Draw a labelled force and free-body diagram indicating all the forces acting on the object.</td></tr>
<tr><th colspan="2">Solution</th></tr>
<tr><th>Force diagram</th><th>Free-body diagram</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

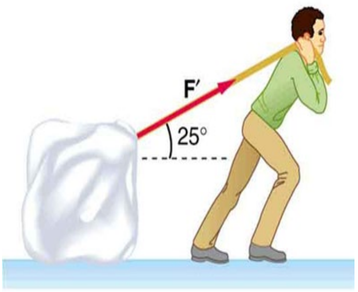
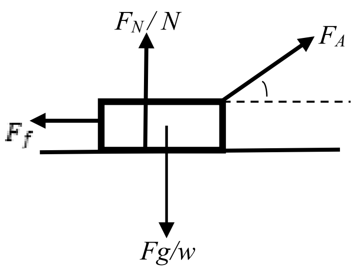
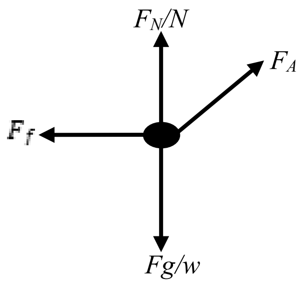
2.1 Forces acting on an object on a horizontal rough surface

Force diagram	Free Body diagram
	

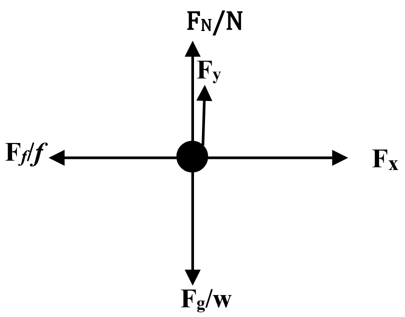
2.2 Forces acting on a suspended object

Scenario	Force diagram	Free Body diagram
		
Byjus.com		

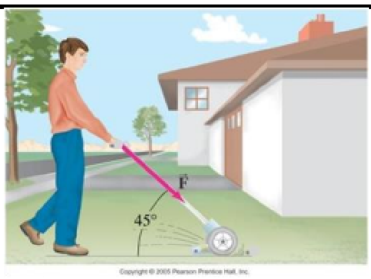
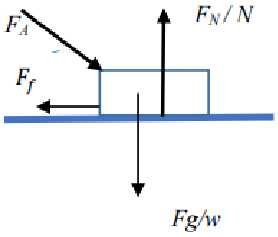
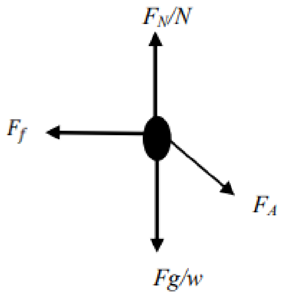
2.3 Forces acting on an object on a horizontal surface/plane pulled at an angle

Scenario	Force Diagram	Free Body Diagram
		
Taken from https://images.app.goo.gl/MCVVXQrLetL8aaje8		

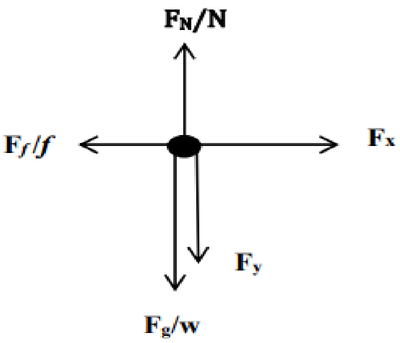
RESOLVE F_A /$F_{applied}$ INTO COMPONENTS AND DRAW A FREE BODY DIAGRAM

Free-body diagram showing components of F_A /$F_{applied}$ puling an object at an angle.

• The vertical component of the force points upwards: $F_y = F\sin\theta$ • The horizontal component will point to the right: $F_x = F\cos\theta$ • The horizontal component will point to the right. • Normal force F_N is **NOT** equal to F_g i.e. $F_N \neq F_g$. $F_N + F_y = F_g$

2.4 **<u>Force acting on an object on a horizontal surface and PUSHED at an angle</u>**

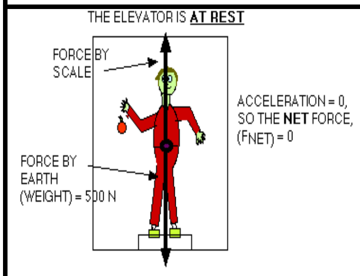
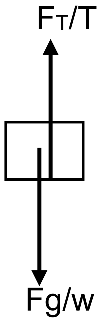
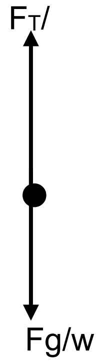
Scenario	Force Diagram	Free Body Diagram
		
Taken from https://images.app.goo.gl/tRaLWAobLFCshty19		

RESOLVE F /F$_{applied}$ INTO COMPONENTS AND DRAW A FREE BODY DIAGRAM

Free-body diagram showing components of F /F$_{applied}$

• The vertical component of the force points downwards: $F_y = F\sin\theta$ • The horizontal component will point to the right: $F_x = F\cos\theta$ • The horizontal component will point to the right. • Normal force F_N is **NOT** equal to F_g i.e. $F_N \neq F_g$. • $F_N = F_g + F_y$.

2.5 FORCES ACTING ON SUSPENDED OBJECTS

2.5.1 Stationary Lift / moving at constant velocity

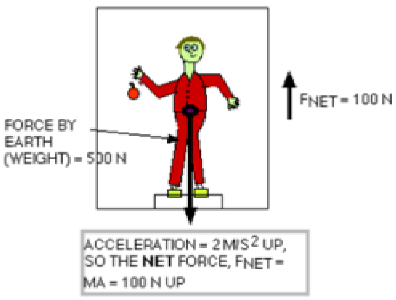
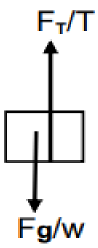
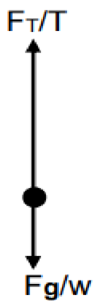
<table>
<tr><th>Scenario</th><th>Force Diagram</th><th>Free Body Diagram</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td colspan="3">Taken from https://images.app.goo.gl/hESbPoWmQ7SeLNBw6</td></tr>
</table>

- $F_{net} = 0$ N

$F_g + (-F_T) = 0$ N

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

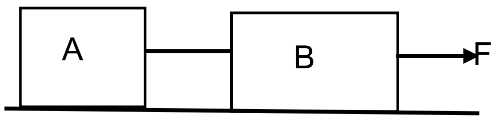
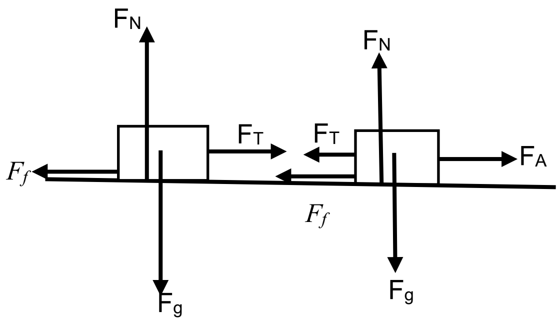
2.5.2 Lift **accelerating** (Upward or Downward)

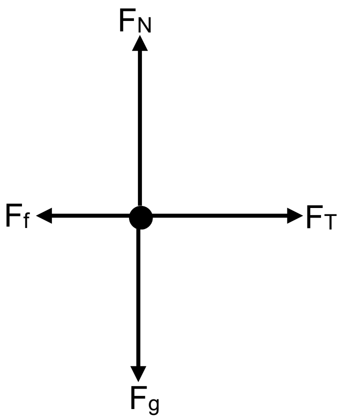
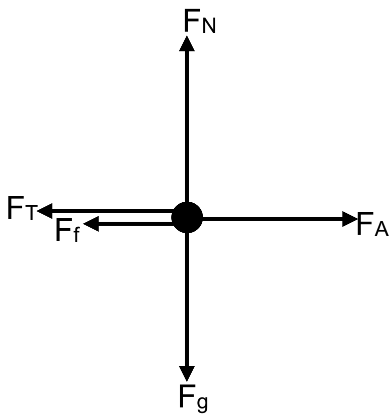
<table>
<tr><th>Scenario</th><th>Force Diagram</th><th>Free Body Diagram</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Taken from https://images.app.goo.gl/Tgd9pzbxaGouAPSK6</td><td></td><td></td></tr>
</table>

NB: Acceleration will be in the direction of the **greatest force** and **in this example** the lift is accelerating upwards.

2.6 FORCES ACTING ON OBJECTS ATTACHED BY ROPE OR CABLE

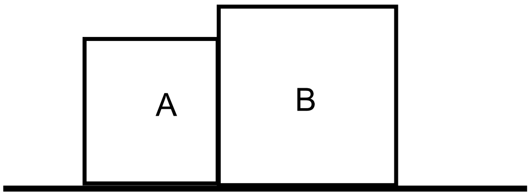
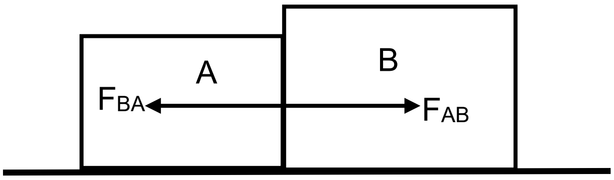
- The objects move at the same speed and acceleration.
- Applied forces are applied to only one object at a time.
- The tension in the rope is the same, but point in opposite directions.

Scenario	Force Diagram
	

Free body diagrams	
	

2.7 **FORCES OBJECTS EXERTS ON EACH OTHER WHEN ARE IN CONTACT (TOUCHING EACH OTHER).**

NB: When objects are in contact, object A exerts a force on object B, object B simultaneously exerts an oppositely directed force of equal magnitude on object A**.** (Newton’s Third Law of Motion).

<table>
<tr><th>Scenario</th><th>Force Diagram</th></tr>
<tr><td>
</td><td>

F_{BA} = Force of object B exerted on object A.
F_{AB} = Force of object A exerted on object B.</td></tr>
<tr><td colspan="2">Free Body Diagram of ONLY forces the objects exerts on each other.</td></tr>
<tr><td colspan="2">
</td></tr>
</table>

3 **NEWTON'S LAWS OF MOTION**

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At the end of the lesson learners must be able to:

- State **ALL** three Newton's laws of motion in words namely:
  - Newton's First Law of Motion
  - Newton's Second Law of Motion
  - Newton's Third Law of Motion
- Apply the laws to solve any given real life situation(s).
- Predict and explain different phenomena using the laws of motion.

3.1 NEWTON'S FIRST LAW OF MOTION

Newton's first law of motion; states that an object continues in a state of rest or uniform velocity unless it is acted upon by an unbalanced (net or resultant) force.

- Newton's first law of motion is also known as the **Law of inertia.**

3.1.1 **INERTIA** is the property of a body to **resist any change** in its state of motion or rest.

- Inertia **depends on the mass** of an object:
  - Heavier objects have greater inertia than lighter objects.

3.1.2 **MASS** is the measure of the inertia of the body **or** the quantity of matter.

- It is measured in kilogram (kg).

3.1.3 **Use of Newton's First Law of Motion in everyday life**

Wearing of seat belts

According to Newton's First Law of Motion, *"an object will continue in a state of rest or uniform motion (constant velocity) unless a non-zero net force acts upon it".*

How does a seat belt assist in reducing serious injuries during collision?

- When a car collides and comes to a sudden stop, the person inside the car will continue moving forward due to inertia.
- Without a safety belt, the person will make contact with the windscreen of the car, causing severe injuries.
- The safety belt counteracts the inertia, preventing the forward motion of the person.

3.2 NEWTON'S SECOND LAW OF MOTION

Newton's Second Law of Motion*; states that,* when a resultant/net force is applied to an object of mass, m, it accelerates the object in the direction of the net force. The acceleration is directly proportional to the resultant/net force and inversely proportional to the mass of the object.

3.2.1 The formula that we use to represent Newton's second law of motion is:

$$\boxed{F_{net} = ma}$$

Where:

F_{net} = the force in Newton **(N)**

m = the mass of an object in kilogram **(kg)**

a = the acceleration of an object in meters per second squared **($m \cdot s^{-2}$)**

3.2.2 Acceleration ('a ')

- is the rate of change of velocity.
- can be calculated using formula:

$$a = \frac{\Delta v}{\Delta t}$$

- is measured in $m{\cdot}s^{-2}$

3.3 NEWTON'S THIRD LAW OF MOTION

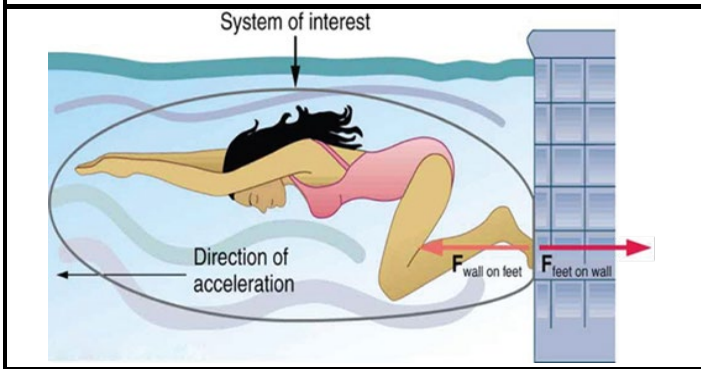
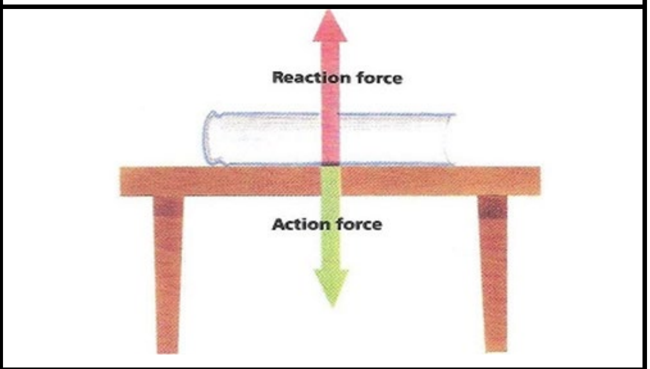
- ***Newton's Third Law of Motion****; states that when object A exerts a force on object B, object B simultaneously exerts an oppositely directed force of equal magnitude on object A.*
- Newton's Third Law of Motion describes action-reaction force pairs. These forces act on different objects.

$$\boxed{F_{\mathbf{A}\text{ on }\mathbf{B}} = -F_{\mathbf{B}\text{ on }\mathbf{A}}}$$

3.3.1 Properties of action-reaction force pairs

- Equal in magnitude
- Opposite in direction
- Acts on different objects

3.3.2 **<u>Examples of action-reaction pairs</u>**

<table>
<tr><th>Figure A</th><th>Figure B</th></tr>
<tr><td>
</td><td>
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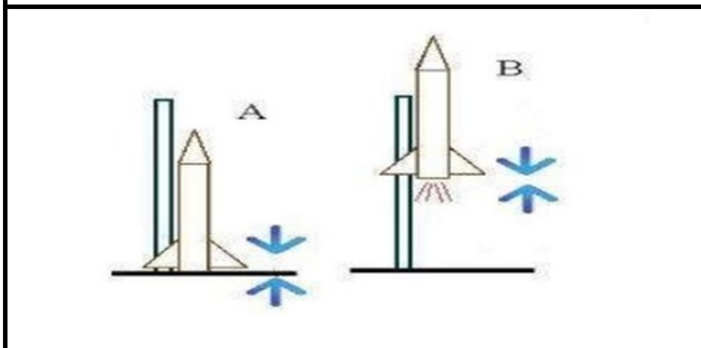
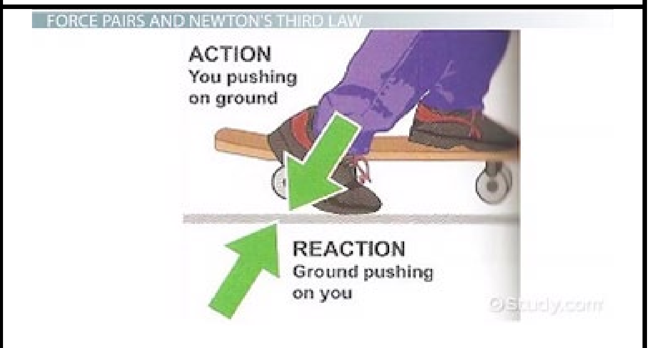
https://images.app.goo.gl/eMDX7bynmJojhcKF6</td></tr>
<tr><th>Figure C</th><th>Figure D</th></tr>
<tr><td>
</td><td>
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https://images.app.goo.gl/48tbRVha8FYCR87S6</td></tr>
</table>

3.3.3 **Explanation of Action-Reaction pairs figures**

Figure A: The swimmer pushes the wall backwards with her feeds, simultaneously the wall then pushes the swimmer forward.

Figure B: A book on the table exerts a force, (w = mg) on the table downwards, and the table exerts equal but upwards force (normal force) on the book.

Figure C: Space rockets are propelled by recoil. The rapidly expanding gases which escape from the combustion chamber experiences a downward force, this escaping gas will then exert an equal force, which pushes the rocket upwards.

Figure D: When a person walks, his legs and toe muscles exert a force on the floor in a slanted, downward direction. The floor exerts an equal but opposite force, which pushes the person forward.

TIPS ON HOW TO ANSWER QUESTIONS

- Analyse the given statement and look for key words such as constant velocity ($a = 0$ and $F_{net} = 0$).
- Determine the direction of motion (displacement) of each object.
- Draw labelled free body diagrams indicating all the forces acting parallel to the displacement.
- Apply newton's second law on each object and add the forces.
- Take the direction of motion of each object as a positive direction and the opposite as negative and determine the equations.
- Add the equations to determine any variable.

WORKED EXAMPLE

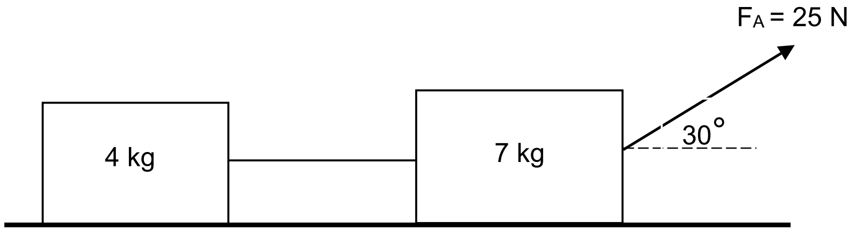
QUESTION 1 (QUESTION 2 DBE/2018 EXEMPLAR)

1.1 On the way to work an electrician put a toolbox of mass 2 kg on the backseat of the car. A co-worker in the passenger seat noticed that children were crossing the road and shouted that the electrician should stop. The electrician applied the brakes suddenly and the car stopped.
During the braking period the passenger's body of mass 68 kg moved to the edge of the seat and the toolbox fell from the backseat.

1.1.1 Name and state the law of motion that could be used to explain the situation above. (3)

1.1.2 Which ONE, the passenger's body or the toolbox, had more inertia? Explain the answer. (2)

1.2 Two blocks of 4 kg and 7 kg are connected by a light inextensible string. A force of 25 N is applied at an angle of 30° to the horizontal on the 7 kg block, as shown in the diagram below. The system moves to the east. Each block experiences a frictional force of 4,5 N.



1.2.1 State Newton's Second Law of Motion in words. (2)

1.2.2 Draw a labelled free-body diagram indicating ALL the forces acting on the 7 kg mass. (5)

Calculate the magnitude of the:

1.2.3 Acceleration of the system (6)

1.2.4 Tension in the string (2)

Solutions to worked out examples

1.1.1 Newton's first law. ✓

An object will remain at rest or continue moving at a constant velocity (or at constant speed in a straight line) ✓ unless acted upon by a non-zero external resultant force. ✓ (3)

1.1.2 The passenger's body. ✓

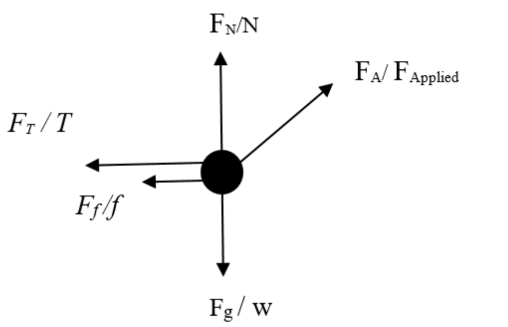
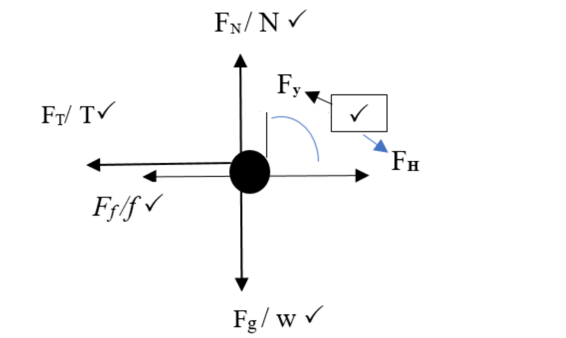
- The mass of the passenger is greater than that of the tool box. ✓

OR

- Inertia is determined by the object's mass; the greater an object's mass, the greater is its inertia. ✓ (2)

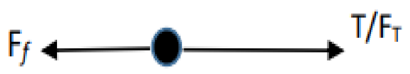
1.2.1 When a net force F_{net} is applied to an object of mass (m) it accelerates in the direction of the net force✓✓. (This acceleration is directly proportional to the net force and inversely proportional to the mass of the object) (2)

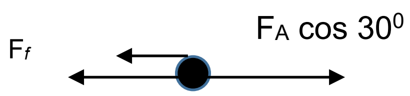
1.2.2

OPTION 1	**OPTION 2**
	

(5)

1.2.3 **For 4 kg block** **For 7 kg block**





F_{net} = ma
T+(- F_f)= ma
T- F_f = ma
T – 45 ✓ = 4a
T = 4a + 45...(1)

✓Any one of these

F_{net} = ma
$F_A$cos30^0 +(– T) +(– F_f) = ma
$F_A$cos30^0 – (T + F_f) = ma

Combine (1) and (2)

250x0,866✓ – (4a + 45 + 45✓) =7a✓...(2)
216,5 – 90 = 7a + 4a
126,5 = 11a
a = 11,5 m.s^{-2} ✓ (6)

1.2.4

OPTION 1	**OPTION 2**
$T = 4a + 45$ $= 4(11,5) + 45$ ✓ $= 91$ N ✓	$F_a\cos 30^0 - (T + F_f) = ma$ $250 \times 0,866 - (T + 45) = 7a$ $216,5 - 45 - T = 7(11,5)$ ✓ $T = 171,5 - 80,5$ $T = 91$ N ✓

(2)

NEWTON'S LAWS OF MOTION ACTIVITIES

NOTES TO LEARNERS:

- Attempt these activities individually and share your workings with your classmates.
- All questions to be answered in an activity book **NO** loose papers.
- Consult with your teacher for any challenges encountered.

QUESTION 1: Multiple Choice Questions

Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A-D) next to the question number (1.1-1.16) in the ANSWER BOOK, e.g. 1.17 D.

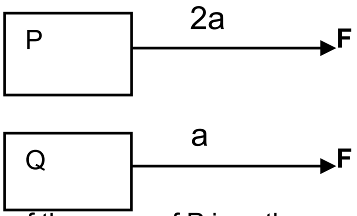
1.1 The driver of a car, travelling East, places a book on the dashboard in front of him while travelling at a constant speed. If the car stops suddenly, in which direction will the book move?

A East
B West
C North
D South (2)

1.2 An object's state of motion in equilibrium remains unchanged until…
A it changes direction.
B there is a non-zero net force acting on the object
C its velocity equals its acceleration.
D all forces acting on the object are balanced (2)

1.3 One of the properties of action-reaction pairs is that…
A Their net force is always zero.
B They act towards the same direction.
C They have the same magnitude.
D They act on the same object. (2)

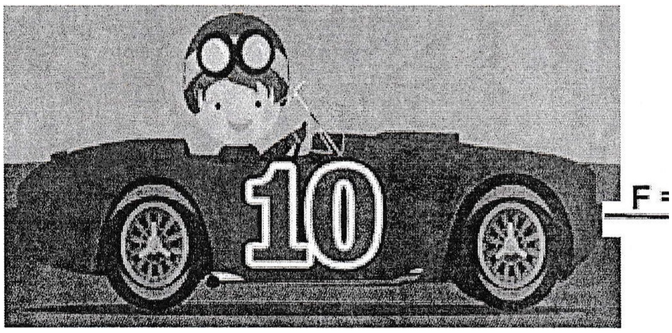
1.4 Two identical forces, each of magnitude F, act at the same time on two different objects P and Q. The acceleration of P is twice the acceleration of Q.



The magnitude of the mass of P is …the mass of Q

A Same as
B Thrice
C Twice
D Half (2)

1.5 A toy racing car of weight 30 N is moving on a straight level road with a rough surface at a constant velocity. The force of the engine of the car is 50 N and the magnitude of the frictional force is 20 N Which one of the following is the magnitude of the resultant force acting on the car?



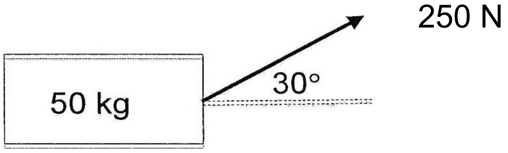
50 N

A 30 N
B 0 N
C 70 N
D 100 N (2)

1.6 Newton's First Law of Motion implies that an object will continue moving at a constant velocity as long as the…

A net force experienced by the object is greater than zero.
B Sum of all forces acting on the object is zero.
C net force experienced by the object is less than zero.
D Sum of all the forces acting on the object is greater than zero but less than one. (2)

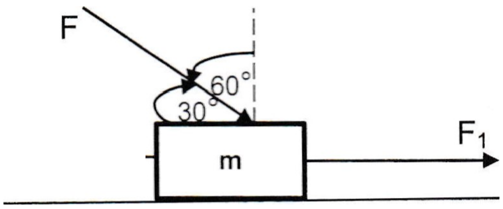
1.7 A 50 kg object is lying on a horizontal surface. A force of 250 N is applied to the object at an angle of 30^0 to the horizontal.



Which one of the following statements is TRUE for the normal force? The normal force is equal to:

A 490 N
B 365 N
C 250 N
D 500 N (2)

1.8 An object of mass, m, moves to the right with a non-zero acceleration under the influence of the forces as indicated below.



A $f_k = F_1 - F\ Sin 60^0$
B $f_k = F_1 + F\ Cos 60^0$
C $f_k = F_1 - F\ Cos 30^0 - ma$
D $f_k = F_1 + F\ Cos 30^0 - ma$ (2)

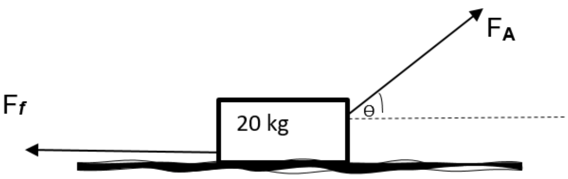
1.9 An object resists a change in its state of motion or rest because of its ...

A Momentum.
B Change in direction.
C Inertia.
D Impulse. (2)

1.10 Which ONE of the following statements is CORRECT about inertia?

A Inertia is equal to the force applied.
B Inertia is always equal to the force applied.
C Inertia is determined by the mass.
D Inertia is determined by the direction of motion. (2)

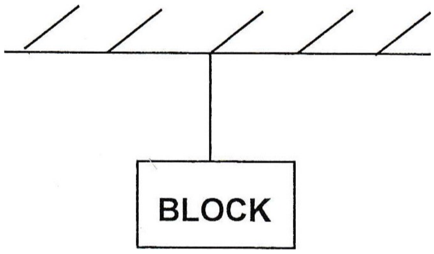
1.11 The block of mass 20 kg in the diagram below, moves towards the east at a CONSTANT VELOCITY across a rough horizontal surface.



The velocity is constant because…

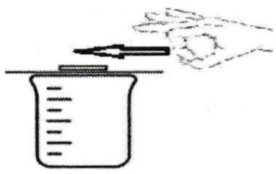
A $F_f = F_A$ and $a = 9{,}8\ m.s^{-2}$
B $F_A < F_f$ and $a = 0\ m.s^{-2}$
C $F_A \sin\theta = F_f$ and $a = 9{,}8\ m.s^{-2}$
D $F_A \cos\theta = F_f$ and $a = 0\ m.s^{-2}$ (2)

1.12 A block is suspended by a single, vertical string from the ceiling. Which forces form a Newton's third law pair' with the weight of the block?



A The force from the ceiling acting on the block
B The force of tension in the string acting on the block.
C The gravitational force by the block on the Earth.
D The weight of the block has no "Newton's third law pair as the block is in equilibrium (2)

1.13 A small coin is placed on a smooth piece of cardboard and then put on the mouth of a glass as shown below. When the sheet of paper is quickly flicked away with a finger horizontally, the coin drops into the glass.



This is an application of…

A Conservation of momentum
B Newton's Second law
C Force of gravity
D Newton's First Law (2)

1.14 Newton's Second Law of Motion can be stated as:

A The force applied to an object, or Applied Force **(F applied)** is equal to the acceleration.

B If object A exerts a force on object B, at the same time object B will exert an equal force on object A, in the opposite direction

C The resultant force Fnet is equal to the mass of the object multiplied by the speed of the object.

D If a resultant force **(F_{net})** is applied to an object with mass **(m),** the object will accelerate in the direction of the resultant force. (2)

1.15 Measure of the inertia of a body is…

A weight

B velocity

C inertia

D mass (2)

1.16 A fly hits the windscreen of a speeding car with a force *F*. Which one of the following statements is true?

The force of the windscreen on the fly …

A is equal to F.

B is smaller than F

C is greater than F

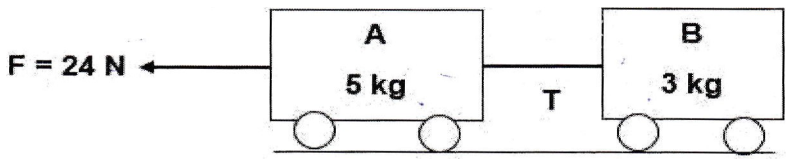
D cannot be determined (2)

[32]

Structured Questions

QUESTION 2 **(QUESTION 2 EC JUNE 2018)**

Trolley **A**, of mass 5 kg and trolley **B** of mass 3 kg, both initially at rest on a frictionless surface, are joined by a light string of negligible mass. A force F of 24 N is applied on trolley A as shown in the diagram.



2.1 Draw a free body diagram showing all the forces acting on trolley **A**. (4)
2.2 State Newton's Second Law of motion. (2)
2.3 Calculate the acceleration of trolley **A**. (4)
2.4 Calculate the tension T on the string. (3)
2.5 What would happen to the value of T if:
(Write down only **INCREASES**, **DECREASES** or **REMAINS THE SAME**)Show by explanation or calculation on how you arrive at the answer.

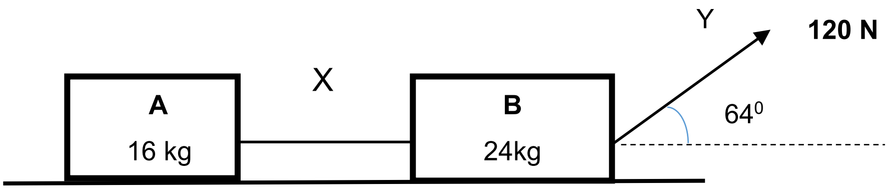
2.5.1 The force, **F,** is acting at an angle 30 ^{0} horizontally. (2)

2.5.2 The mass of trolley A is decreased. (2)

[17]

QUESTION 3 **(QUESTION 2 KZN Common Test March 2019)**

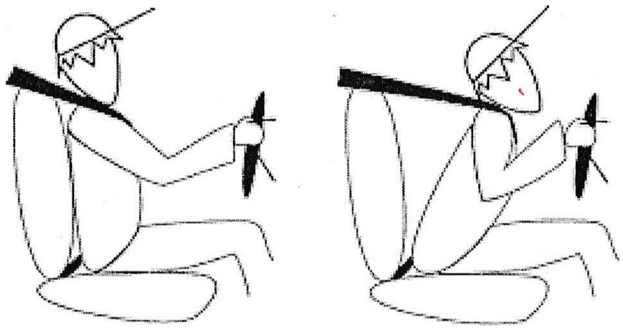
3.1 A worker, at a construction site, pulls two blocks A and B of masses 16 kg and 24 kg respectively across a rough horizontal surface by means of a light inextensible rope, Y, inclined at 64 ^{0} to the horizontal. The 16 kg and 24 kg blocks experience frictional forces of 3, 5 N and 4 N, respectively.



The worker exerts a constant force of 120 N on block B. The blocks are joined by a light inextensible bar, X. The masses of rope Y and bar X are negligible compared with those of blocks A and B.

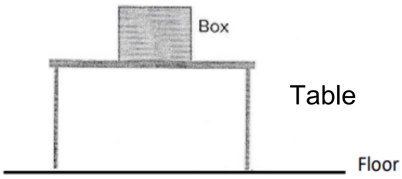
3.1.1 State Newton's Second Law of Motion in words. (2)
3.1.2 Draw a labelled free-body diagram showing ALL the forces acting on the 24 kg block (5)
Calculate:
3.1.3 The normal force on block B (3)
3.1.4 Coefficient of kinetic friction on block B (4)
3.1.5 Acceleration of the system (6)
3.1.6 Tension in bar X (2)

3.2 A dummy car is moving at a constant velocity with a dummy driver inside and suddenly it hits a wall that was ahead. The diagram below shows what is happening to the dummy driver when a dummy car hits the wall.



Name and **state** the law of motion that could be used to explain the situation above. (3)

3.3 Identify the action-reaction pairs acting in the diagram below

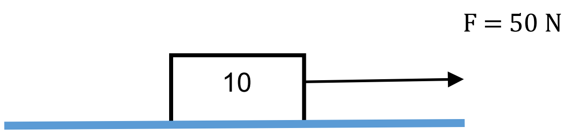


(2)

[27]

QUESTION 4 **(QUESTION 2 FS JUNE 2019)**

A box, mass 10 kg, is initially at rest on a rough surface. A horizontal force ***F*** of 50 N is applied to the box causing it to accelerate. The frictional force acting on the box is 30 N.



4.1 State Newton's First Law of Motion in words (2)

4.2 Draw a free-body diagram of the box showing all the forces acting on it. (4)

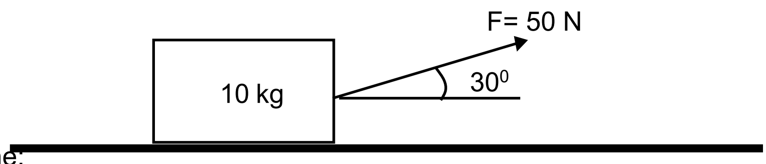
4.3 Calculate the magnitude of the:

4.3.1 Weight of the box (3)

4.3.2 Acceleration of the box (3)

4.4 Define the term ***frictional force***. (2)

4.5 The 50 N force is now applied to the box at an angle of 30° to the horizontal.



Calculate the magnitude of the:

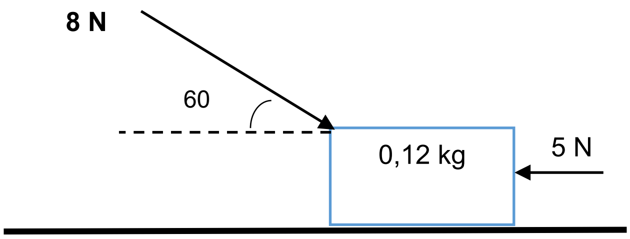
4.5.1 Vertical component of the 50 N force (2)

4.5.2 Normal force acting on the box (3)

[19]

QUESTION 5 **(QUESTION 2 GP SEPT 2019)**

5.1 Two learners, A and B, are using a block of mass 0,12 kg as a toy car. Learner A is pushing the toy car with a force of 8 N at an angle of 60^0 to the right and Learner B is pushing the same block with a force of 5 N to the left. The block experiences a frictional force of 0,3 N horizontally to the surface as shown in the diagram below.



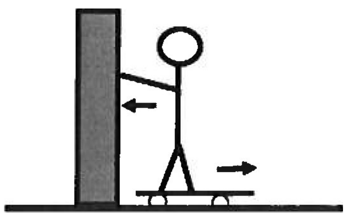
5.1.1 Name and state the law that can be used to explain the movement of the block (3)

5.1.2 Draw a free-body diagram of all the forces acting on the block. (5)

5.1.3 Calculate the magnitude and direction of the net force (5)

5.1.4 Calculate the magnitude of the acceleration of the block (3)

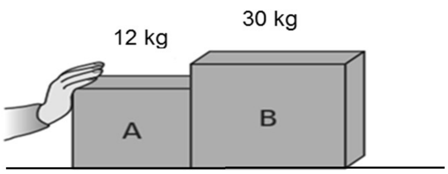
5.2 A boy is standing on his skateboard next to a solid wall. As soon as he pushes against the wall, he moves in the opposite direction.



5.2.1 Use relevant law of motion to explain why the boy moves to the opposite direction after pushing against the wall. (3)

QUESTION 6 **(QUESTION 3 DBE/NOV 2019)**

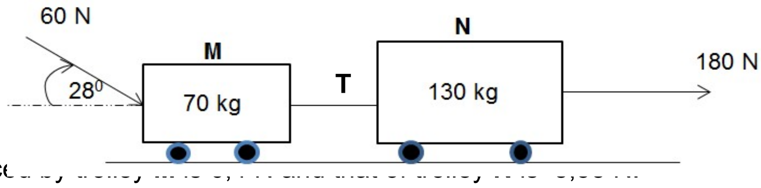
6.1 Crate **A** and crate **B**, of different masses, are placed next to each other on a horizontal rough surface. A hand pushing crate **A** causes both crates to accelerate at 2,3 m.s^{-2} to the right. Crate **B** experiences a frictional force of 25,3 N.



6.1.1 State Newton's Third Law of Motion in words. (2)

6.1.2 Calculate the force exerted by crate **B** on crate **A**. (5)

6.2 Two workers, A and B, are moving two trolleys, **M** and **N**, connected by a light inextensible string, as shown in the diagram below. Worker A pulls trolley **N** with a force of 180 N to the east. Worker B pushes trolley **M** with a force of 60 N at an angle of 28° with the horizontal.



The frictional force experience

6.2.1	State Newton's Second Law of Motion in words.	(2)
6.2.2	If the system accelerates at 1,09 $m.s^{-2}$, calculate the tension (**T**) in the string.	(4)
6.2.3	If worker A pulling force is now applied at an angle of 60° with the horizontal, what will happen to the frictional force experienced by trolley **N?** Write only **INCREASES, DECREASES or REMAINS THE SAME**.	(1)
6.2.4	Explain the answer to **QUESTION 6.2.3.**	(3)

[17]

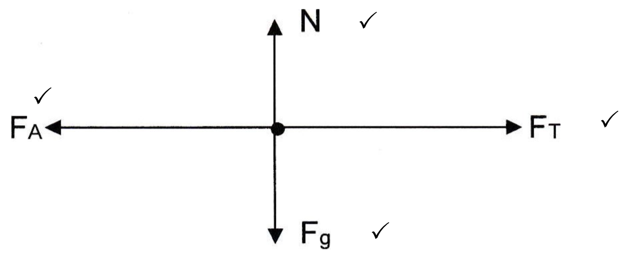
NEWTON'S LAWS OF MOTION RESPONSES TO QUESTIONS

QUESTION 1: Multiple-Choice Questions

1.1 A ✓✓	1.2 B ✓✓	1.3 C ✓✓	1.4 D ✓✓	1.5 A ✓✓	1.6 B ✓✓
1.7 B ✓✓	1.8 D ✓✓	1.9 C ✓✓	1.10 C ✓✓	1.11 D ✓✓	1.12 B ✓✓
1.13 D ✓✓	1.14 D ✓✓	1.15 D ✓✓	1.16 A ✓✓		**2 x16 = 32**

QUESTION 2 START FROM HERE

2.1



Accept labels:

N : F_N /F_{Normal}/ Normal Force

F_g: w/F_w/Gravitational force/Weight

T: F_T/Tension

F_A: Applied force/$F_{Applied}$ / 24 N **(NB:** Do not accept F_{app}**)** (4)

2.2 When a net force acts on an object, the object will accelerate in the direction of the net force ✓✓

OR

When a net force acts on an object, the object will accelerate in the direction of the net force. This acceleration is directly proportional to the net force and inversely proportional to the mass of the object. ✓✓

(2)

2.3

For object **A:**	For object **B:**
$F_{net} = ma$ ✓ $F + (-T) = (5)(a)$ ✓ $24 - T = 5a$........(1) Substitute (T) in (1) $24 - 3a = 5a$ $a = \frac{24}{8}$ $a = 3\ m.s^{-2}$ ✓	$F_{net} = ma$ $T = 3a$..................(2) ✓

(4)

2.4 **POSITIVE MARKING FROM 2.3**

OPTION: 1	OPTION: 2
From eqn (1) $24 - T = 5a$✓ $24 - T = 5(3)$ ✓ $T = 9\,N$ ✓	From eqn (2) T = 3a✓ T = 3(3) ✓ T = 9 N✓

(3)

2.5.1 **DECREASES,** ✓ (2)

If (F_A) 24 N is acting at an angle 30^0 to the horizontal:

F_A= 24 Cos 30

= 21 N

Then

For object A:

$F_{net} = ma$

$F + (-T) = (5)(a)$

(24 Cos 30)- T= 5a

21 – T = 5a……………(1)

For object B:

$F_{net} = ma$

$\mathbf{T = 3\,a}$……………(2)

Substitute (T) in (1)

21 - 3a= 5 a

a**= 2,63** $m.s^{-2}$

OR

But from **eqn (1)**

21 – T = 5a

21 – T = 5(2,63)

T = 7,85 N **(8 N)**

Therefore T will **DECREASE**

But from **eqn (2)**

$T = 3a$

= (3) (2.63)

= 7,89 N **(8 N)**

2.5.2 **INCREASES** ,✓ (2)

For mass of **Trolley A**, Choose any number **LESS THAN** 5 (kg) but **GREATER THAN** Zero (0) kg and follow the steps above **(2.5.1)** to find the value of **T.**

[17]

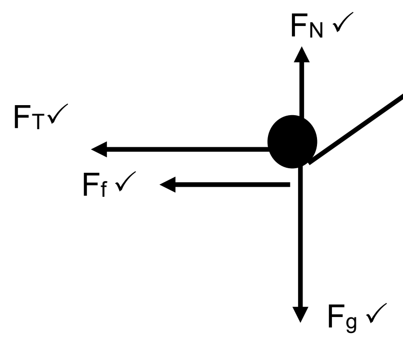
QUESTION 3

3.1.1 When a net force acts on an object, the object will accelerate in the direction of the net force. ✓✓

OR

When a net force acts on an object, the object will accelerate in the direction of the net force. This acceleration is directly proportional to the net force and inversely proportional to the mass of the object. ✓✓ (2)

3.1.2



Accept labels:

N : F_N / F_{Normal} / Normal Force

F_g : w/Gravitational force/Weight

T: F_T/Tension

F_A: Applied force/ $F_{Applied}$ /120N

NB: Do not accept ***F_{app}*** (5)

3.1.3 $N = mg - F_y$

$= (24)(9{,}8)$ ✓ $- (120 \text{ Sin } 64^0)$ ✓

$= 127{,}44$ N ✓ (3)

3.1.4 $f_k = \mu_k N$ ✓

4 ✓ $= \mu_k(127{,}44)$ ✓

$\mu_k = 0{,}03$ ✓ (4)

3.1.5 **For block A:**

$F_{net} = ma$ ✓

$T + (-F_f) = ma$

$T - 3{,}5 = 16a$…………………….. **(1)** ✓

For block B:

$F_{net} = ma$

$120 \cos 64^0 + (-4 - T) = 24a$ ✓

$48{,}60 - T = 24a$…………………… **(2)**

Solving eqn **(1)** and **(2)**

$48{,}60 - (16a + 3{,}5) = 24a$ ✓

$a = 1{,}13 \ m.s^{-2}$ ✓ to the right ✓ (6)

3.1.6 T-3,5= 16a

T-3,5= 16$(1,13)$ ✓

T = 18,08 + 3,5

= 21,58 N ✓ (2)

3.2 Newton's First Law ✓

An object continues in a state of rest or uniform (moving with constant) velocity (v) ✓ unless it is acted upon by a net (resultant) force. ✓ (3)

3.3 Force by the box on the table and force by the table to the box ✓✓

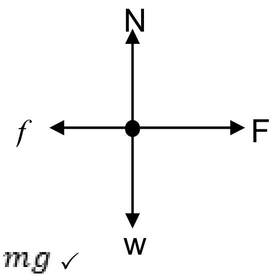
OR

Force by the table on the floor and force by the floor on the table ✓✓ (2)

QUESTION 4

4.1 An object continues in a state of rest or uniform (constant) velocity ✓ unless it is acted upon by a net (resultant) force ✓

4.2



	Accepted labels	Mark
w	F_g / F_w / weight / mg / gravitational force	✓
f	$F_{friction}$ / F_f / friction / Frictional force / f_k	✓
N	F_N / F_{normal} / Normal force / Force of surface on box	✓
F	F_A / $F_{Applied}$	✓
NB: Do not accept F_{app}		

(4)

4.3.1 $w = mg$ ✓

= (10)(9,8) ✓

= 9,8 N ✓ (3)

4.3.2

OPTION 1	**OPTION 2**
$F_{net}=ma$ 50 + (-30) ✓ = (10) a ✓ $a = 2\ m \cdot s^{-2}$ ✓	$F_{net} = F_A + F_f$ = 50 + (- 30) = 20 N **Then:** $F_{net}=ma$ ✓ 20 = 10 a ✓ $= 2\ m \cdot s^{-2}$ ✓

(3)

4.4 Is the force parallel to the surface that opposes the motion of an object ✓ and acts in the direction opposite the motion of the object ✓ (2)

4.5.1 $F_y = F\ Sin\theta$

$= 50\ Sin\ 30^0$ ✓

$= 25\ N$ ✓ (2)

4.5.2

OPTION 1	**OPTION 2**
Let the **upward** Force be positive $F_{net} = ma$ $N + F_y + (-w) = 0$ ✓ $N + Fsin\theta + (-mg) = 0$ $N + (50)(0,5) - (10)(9,8) = 0$ ✓ $N = 73\ N$ ✓	Let the **downward** Force be positive $F_{net} = ma$ $N + F_y + (-w) = 0$ ✓ $N + Fsin\theta + (-mg) = 0$ $N + (50)(0,5) - (10)(9,8) = 0$ ✓ $N = 73\ N$ ✓

(3)

QUESTION 5

5.1.1 Newton's Second Law ✓

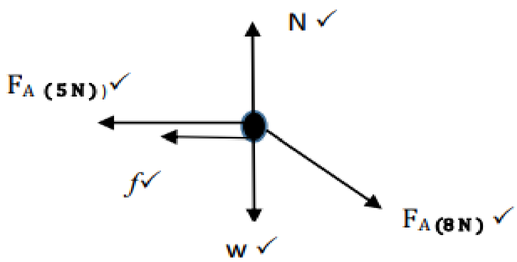
When a net force acts on an object, the object will accelerate in the direction of the net force. ✓✓

OR

When a net force acts on an object, the object will accelerate in the direction of the net force. This acceleration is directly proportional to the net force and inversely proportional to the mass of the object. ✓✓

(3)

5.1.2



	Accepted labels	**Mark**
w	F_g / F_w / weight / mg / gravitational force	✓
f	$F_{friction}$ / F_f / friction / Frictional force / f_k	✓
N	F_N / F_{normal} / Normal force / Force of surface on box	✓
F	F_A / $F_{Applied}$	✓
NB: Do not accept F_{app}		

(5)

5.1.3 Let to the **right** be positive

Force applied by Learner A:

$F_H = F_A\ Cos\theta$

$= 8\ Cos\ 60^0$

$= 4$ N to the right

$F_{net} = F_{(Learner\ A)} + (-F_{friction}) + (-F_{(Learner\ B)})$ ✓

$= 4 + (-0,3)$ ✓ $+ (-5)$ ✓

$= -1,3$ N

$= 1,3$ N ✓ to the Left ✓ (5)

5.1.4 $F_{net} = ma$ ✓

$1,3 = (0,12)\ a$ ✓

$a = 10,83\ m.s^{-2}$ ✓ (3)

5.2.1 **According to Newton's Third Law of Motion:** When a body A (boy) exerts a force on body B (the wall), body B simultaneously exerts an oppositely directed force of equal magnitude on object A. ✓✓ That is why the boy is sliding backwards (in the opposite direction). ✓ (3)

QUESTION 6

6.1.1 When a body A exerts a force on body B , body B simultaneously exerts an oppositely directed force of equal magnitude on object A. ✓✓ (2)

6.1.2 **For crate B**:

Let to the right be positive

$$\left.\begin{aligned} F_{net} &= ma \\ F_{AonB} + (-\ F_f) &= ma \end{aligned}\right\}$$ ✓ any one

$F_{AonB} + (-25,3)$ ✓ $= (30)(2,3)$ ✓

$F_{AonB} = 69 + 25,3$ (5)

$\therefore F_{BonA} = 94,3\ N$ ✓ to the left ✓

6.2.1 When a net force acts on an object, the object will accelerate in the direction of the net force. ✓✓

OR

When a net force acts on an object, the object will accelerate in the direction of the net force. This acceleration is directly proportional to the net force and inversely proportional to the mass of the object. ✓✓

(2)

6.2.2

OPTION 1	**OPTION 2**
<u>TROLLEY **M**</u> $\left.\begin{aligned} F_{net} &= ma \\ T + F_H + f_k &= ma \end{aligned}\right\}$ ✓ any one $T + 60\ Cos\ 28^0 + (-6,4)$ ✓ $= 70 \times 1,09$ ✓ $T + 52,98 - 6,4 = 76,3$ $T = 29,72\ N$ ✓	<u>TROLLEY **N**</u> $\left.\begin{aligned} F_{net} &= ma \\ F_{Paul} + T + f_k &= ma \end{aligned}\right\}$ ✓ any one $180 - T - 8,58 = (130)(1,09)$ 171,42 $-T$= 141,7 T=29,72 N

6.2.3 Decreases (1)

6.2.4
- The vertical upward force will tend to lift the trolley from the floor. ✓

  OR

  There will be a vertical component of the applied force
- The normal force will therefore decrease✓
- Thus the frictional force will decrease✓ (3)

2. MOMENTUM

Chapter Summary

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 (Δp) is

- the difference between final momentum (p_f) and initial momentum (pi)
- a vector quantity (direction is important)
- dependent on Δv

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.

$$\sum p_{before} = \sum p_{after}$$

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} = , therefore

$F_{net}\Delta t = \Delta p$

Impulse is the product of a net force and time ($F_{net}\Delta t$) and is equal to change in momentum.

Formulae: $F_{net}\Delta t = \Delta p$

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

Types of collisions

- Elastic - total kinetic energy is conserved:

$$\sum E_{ki} = \sum E_{kf}$$

- Inelastic – total kinetic energy is not conserved. $\sum E_{ki} \neq \sum E_{kf}$

Total linear momentum is conserved in both types of collisions.

MOMENTUM

1. **Momentum:** Is defined as the product of **mass** and **velocity** of an object.

   Descriptions

- Is a vector quantity (has magnitude and direction).
- Can be calculated using this formula:

  $$\boxed{p = mv}$$

  Where: p = momentum in (kg.m·s^{-1})

  m = mass of an object in (kg)

  v = velocity of an object in (m·s^{-1})
- The SI unit for measurement is kilogram meters per second (kg m·s^{-1})

Tips on solving Momentum problems

1. Write down given information and quantity (unknown data). to be calculated
2. Where necessary convert mass, m, of an object to kilograms (kg).
3. Where necessary convert the velocity of an object to meters per second (m·s^{-1})
4. Copy the formula as given in the data sheet.
5. Substitute all the variables correctly (before manipulating the formula).
6. Write the answer with the correct unit.
7. Always include direction in all momentum calculations / answers

Examples:

1. Calculate the momentum of a cricket ball, mass 158 g, travelling at 2 m·s^{-1} west.
2. Calculate the mass of an object with a momentum of 54 kg. m·s^{-1} moving at a velocity of 6,3 m·s^{-1} Southwards.
3. Calculate the velocity an object, mass 236 g, with a momentum of 136 kg. m·s^{-1} Northerly.

Solutions

1. **Given data**: m = 158 g , $v =$ 2 m.s^{-1} $p = ?$

   First convert **158 g** to **kg** :

   1000 g = 1 kg

   158 g = **x**

   x = 0,158 kg

   $p = mv$

   = (0,158)(2)

   = **0,316 kg. m·s^{-1}west**

2. **Given data**: p = 54 kg. m·s^{-1}, $v =$ 6,3 m·s^{-1} $m = ?$

   $p = mv$

   54 = m x 6,3 (**NB:** Substitute values before making, m, the subject of the formula)

   m = 8,6 kg

3. **Given data**: p = 136 kg. m·s^{-1} m= 236 g ($\frac{236}{1000} = 0,236\ kg$) $v = ?$

$\boldsymbol{p = mv}$

$136 = 0{,}236 \times v$

$\boldsymbol{v = 576{,}27}$ m·s^{-1}Northerly (**NB**: velocity is a vector direction must also be indicated)

1.2. Change in Momentum

When a moving object comes into contact with another object (moving or stationary) it results in a change in velocity for both objects and therefore a change in momentum (p) for each one. The change in momentum can be calculated by using:

$$\Delta \boldsymbol{p} = \boldsymbol{p_f} - \boldsymbol{p_i}$$

Where:

$\Delta p = change\ in\ momentum$ kg. m·s^{-1}

$p_f = final\ momentum$ kg. m·s^{-1}

$p_i = initial\ momentum$ kg. m·s^{-1}

NB: When calculating change in momentum always choose one direction to be positive

Worked out Examples

QUESTION 3 (DBE/NOV 2018)

3.1 A truck of mass 1 000 kg and a car of mass 850 kg approach each other on a frictionless horizontal surface, moving at 12 m·s^{-1} and 25 m·s^{-1}respectively.

The two vehicles collide head-on with each other. After the collision the truck continues to move at 8 m·s^{-1}towards its original direction. Calculate the magnitude of the change in momentum of the truck.

Solution:

3.1 **Given data:**

For Truck: m = 1000 kg , v_i = 12 m·s^{-1} v_f = 8 m·s^{-1}

For Car: m = 850 kg , v_i = 25 m·s^{-1}

Let to the right be positive

$$\Delta p = p_f - p_i$$
= mv_f - mv_i
= 1000 (8 – 12)
= 8000 - 12000
= - 4000 kg. m·s^{-1}
= 4000 kg. m·s^{-1} **to the Left**

2. A 1000 kg car initially moving at a constant velocity of 16 m·s^{-1} in an easterly direction approaches a stop street, starts breaking and comes to a complete standstill. Calculate the change in the car's momentum.

Solution:

Given data: m = 1000kg v_i = 16 m·s^{-1} v_f = 0 m·s^{-1} (standstill = not moving)

Δp = ?

Let east be positive

$$\Delta p = \Delta p_f - \Delta p_i$$
$= mv_f - mv_i$
= (1000)(0) – (1000)(16)
= 1000 - 16000
= - 16000

∴ Δp **= 16000 kg. m·s^{-1} West**

1.3. Newton's Second Law of Motion in terms of Momentum

- ***Newton's Second Law of Motion*** states that, 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.
- The net force acting on an object is equal to the rate of change of momentum.

  ➢ Mathematical expression:

$$\boxed{F_{net} = \frac{\Delta p}{\Delta t}}$$

Where:

F_{net} = resultant force in Newton **(N)**

Δp = change in momentum in kilogram meter per second **(kg.** m·s^{-1}**)**

Δt = time in seconds **(s)**

1.4. IMPULSE

Impulse is the product of the net force acting on an object and the time the net force acts on the object.

Consider the definition of Newton's law of Motion in terms of momentum

$$F_{net} = \frac{\Delta p}{\Delta t}$$

Rearrange the formula

$$\mathbf{F_{net}\, \Delta t} = \Delta p \longrightarrow \textbf{Impulse – momentum theorem}$$

From the equation above

- $F_{net}\Delta t$, is called **Impulse**
- Impulse, $(F_{net}\Delta t)$, is equivalent to the change in momentum, $(\Delta \boldsymbol{p})$.

- ***Impulse-momentum theorem*** can be used to calculate the force exerted, time for which the force

Example

The wicketkeeper in the photograph below catches a cricket ball. The cricket ball, of mass 156 g, was moving at a velocity of 40 m·s^{-1} towards the wicketkeeper. It took the ball 0,8 s to stop in the wicketkeeper's hands.

1.4.1 Determine the magnitude and direction of the impulse experienced by the wicketkeeper.

1.4.2 Calculate the force experienced by the wicketkeeper's hands

Solutions:

1.4.1 **Given data**: $m_{CB} = 156 g$ $(0,156\ kg)$ $v_i = 40\ m$ m·s^{-1} $v_f =$ 0 m·s^{-1} t = 0,8 s

Let towards the wicketkeeper be positive

Convert **grams** to **kilograms:**

$$\frac{156}{1000} = \mathbf{0{,}156\ kg}$$

$\boldsymbol{F_{net}\Delta t} = \boldsymbol{\Delta p}$

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

= 0,156 (0 - 40)

$\boldsymbol{F_{net}\Delta t} =$ **- 6,24 N.s**

∴ the Impulse is 6,24 N.s away from the wicketkeeper

1.4.2 $\boldsymbol{F_{net}\Delta t} = \boldsymbol{\Delta p}$

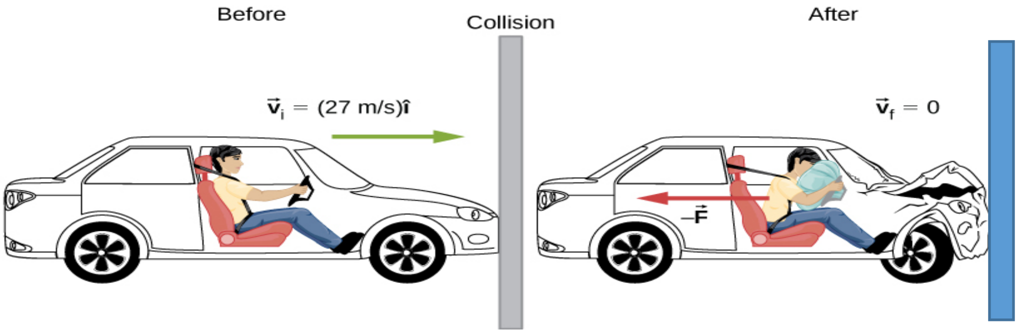
F_{net} (0,8) = 6,24

$\boldsymbol{F_{net} = 7{,}8\ N}$ towards the wicket keeper

1.5. APPLICATION OF IMPULSE IN EVERYDAY LIFE
IMPULSE AND SAFETY

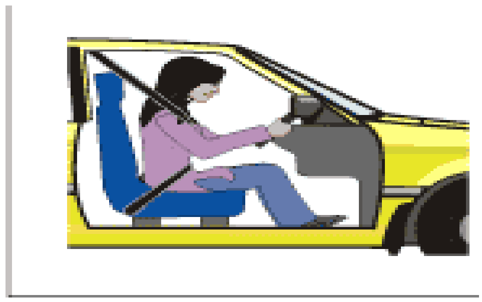
1. **Air bags in cars**

   When an airbag is inflated, it prevents the driver from moving forward during the impact. The collision time (Δt) is increased and the net force on the driver is decreased and injuries reduced.



2. **Seat belts**

   When seat belts are worn during the collision, they increase the time taken (Δt) by the passengers or driver to come to rest during an accident. The net force on the passenger or driver decreases and injuries reduced.

	
Effect of **NOT WEARING** a seat belt during an accident.	Effect of **WEARING** seat belt during an accident.

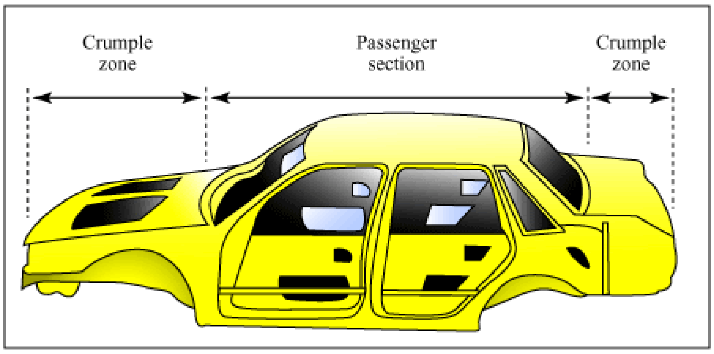
3. **Arrestor Beds**

- An arrester bed is a sand or gravel pathway such as the one shown in pictures below.
- The braking system of a large truck or bus may overheat and fail. If this happens, the truck or bus driver may drive the truck into an arrestor bed, off the main road, to stop the truck.

	
Arrestor bed on the side of main road	**Passenger transport brought to rest safely**

An arrestor increases the time taken (Δt), by the truck or bus to come to rest. The net force exerted on the truck or bus is reduced and the harm to the truck /bus or driver is reduced.

4. **Crumple Zone**

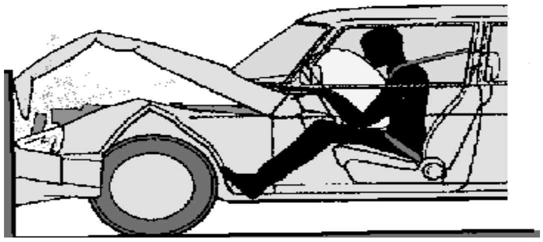


The front and back of the car takes longer to deform during a collision. The collision time (Δt) is increased. The net force on the driver decreases and the risk of injuries is reduced.

EXEMPLAR PROBLEMS

QUESTION 1

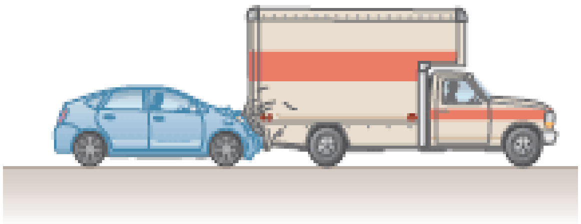
1. Modern vehicles use airbags as a protection system to reduce the risk of death or injury during a collision. These airbags inflate at the moment of collision to reduce the risk of death or injury.



1.1 Use Science principles to explain how airbags serve as a protection system.

QUESTION 2 (Adapted: QUESTION 7 FS/March2020)

2. A man, mass 80 kg and wearing a seat belt, is driving a car which collides with the back of a stationary truck causing the car to come to rest in 0,2 s. Just before the collision, the car is travelling at 20 $m \cdot s^{-1}$



2.1 Calculate the force exerted by the seat belt on the man.

2.2 The front ends of modern cars are deliberately designed to crumple in head-on collisions in order to minimise injuries. Refer to science principles and briefly explain why this design minimises injuries. Support your answer with a relevant equation.

SOLUTIONS TO EXEMPLAR PROBLEMS

QUESTION 1

1.1 When the airbag inflates during the collision the contact time of the passenger or driver with an airbag is longer than without airbag while the change in momentum remains the same. Thus the net force on the passenger or driver is reduced according to the equation $F_{net} = \frac{\Delta p}{\Delta t}$

QUESTION 2

2.1 **Given data:** m = 80 kg $v_i = 20\ m{\cdot}s^{-1}$ $v_f = 0\ m{\cdot}s^{-1}$ t = 0,2s

__Option 1__

Let forward be positive

$$F_{net}\Delta t = \Delta p$$

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

$$F_{net}(0,2) = 80\,(0-20)$$

$$F_{net} = \frac{0-1600}{0,2}$$

$$F_{net} = -8000\ N$$

$$\therefore F_{net} = 8000\ N \text{ backwards}$$

__Option 2__

Let forward be positive

$$a = \frac{v_f - v_i}{t}$$

$$a = \frac{0-20}{0,2}$$

$$a = -100\ m.s^{-2}$$

$$F_{net} = m\,a$$

$$= (80)(-100)$$

$$= -8000\ N$$

$$\therefore F_{net} = 8000\ N \text{ backwards}$$

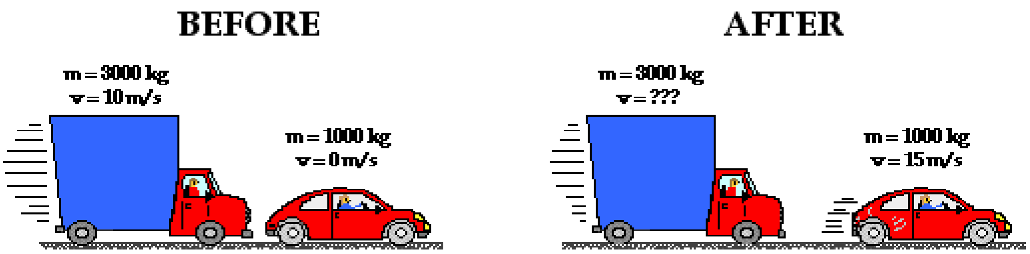
2.2 According to the equation, $F_{net} = \frac{\Delta p}{\Delta t}$, crumpling causes collision time to increase and the net force (F_{net}) on the driver to decrease. This reduces the risk of injuries or death.

1.6 __Conservation of Linear Momentum__

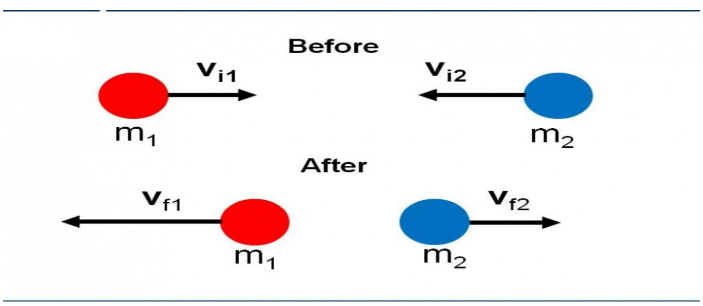
In this section we are going to study:

- Motion (movement) of objects in a straight line (Linear Momentum)
- Different types of collisions (maximum of 2 objects colliding) namely:

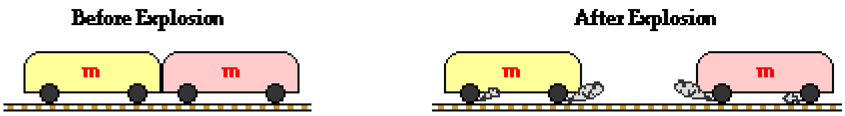
1. **One moving object collides with a stationery object.**



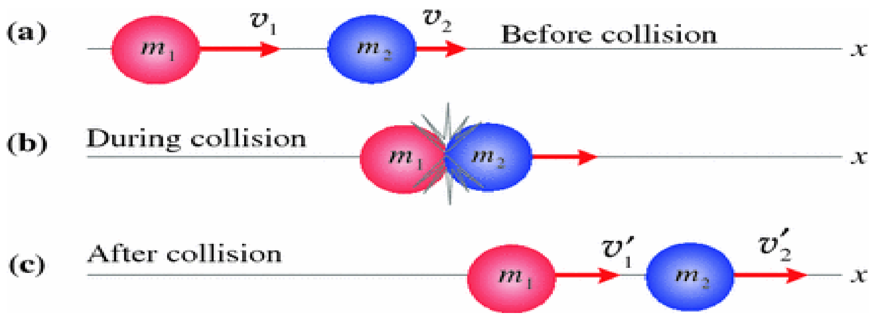
2. **Two objects move towards each other and collide.**



3. One unit separates into parts (explosion) e.g. bomb.



4. Two objects move in the same direction and they collide.



To better understand the above collisions you should familiarize yourself with the following concepts:

- **A system:** a known number of objects and their interactions with each other.
- **Isolated / Closed System:** is the system in which **NO** net external force acts.
  OR
  : is a system in which there are **ONLY** internal forces.
- **External forces:** Forces outside of the system e.g. friction, Force applied.
- **Conserved**: remain constant / remain the same

Elastic collision: a collision where total momentum and total kinetic energy are conserved.

Inelastic collision: a collision where only total momentum is conserved.

1.7. Principle of Conservation of Linear Momentum

- **Principle of conservation of linear momentum** states that, the total linear momentum of an isolated system remains constant in magnitude and direction.
  OR
  In an isolated system the total momentum before collision is equal to the momentum after collision.

Mathematical representation:

$$m_1v_{i1} + m_2v_{i2} = m_1v_{f1} + m_2v_{f2}$$

or

$$\Sigma p_i = \Sigma p_f$$

Where:

Σp_i= the sum of all the objects involved in the collision or explosion before the collision or explosion. (Sum of initial momenta of all the objects)

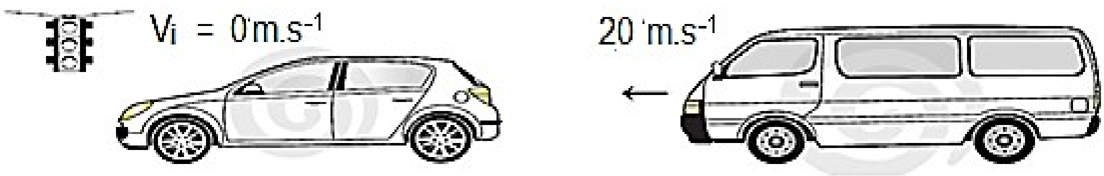
Σp_f= the sum of all the objects involved in the collision or explosion after the collision or explosion. (Sum of final momenta of all the objects)

WORKED EXEMPLAR

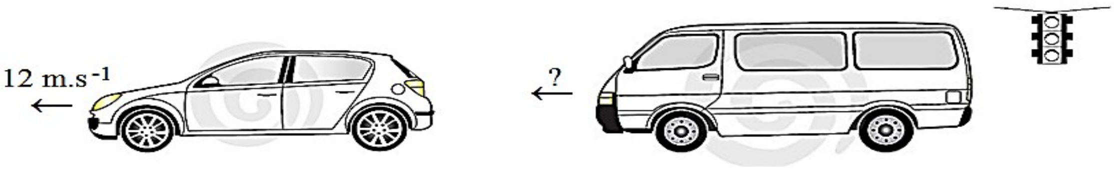
QUESTION 1 (QUESTION 3 EC Sept 2014)

A car of mass 1 500 kg is stationary at a traffic light. It is hit from behind by a minibus of mass 2 000 kg travelling at a speed of 20 m•s^{-1}. Immediately after the collision the car moves forward at 12 m•s^{-1}.

BEFORE



AFTER



1.1 State the **PRINCIPLE OF CONSERVATION OF LINEAR MOMENTUM** in words.

1.2 Calculate the speed of the minibus immediately after the collision.

1.3 The driver of the minibus is NOT wearing a seatbelt. Describe the motion that the driver undergoes immediately after the collision.

1.4 **State** the law of physics which can be used to explain the answer about the motion of the driver in **QUESTION 1.3**

Solutions to exemplar questions

QUESTION 1:

1.1 In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision

OR

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

1.2 **Given data:** m_{car} = 1500 kg v_{icar} = 0 m·s^{-1} v_{fcar} = 12 m·s^{-1}

m_{mbus}= 2000kg v_{imbus} = 20 m·s^{-1} v_{fmbus} = ?

Let to the left be positive

$\Sigma p_i = \Sigma p_f$

$m_{car}v_{icar} + m_{mbus}v_{imbus} = m_{car}v_{fcar} + m_{car}v_{fmbus}$

$(1500)(0) + (2000)(20) = (1500)(12) + (2000)(v_{fmbus})$

$0 + 40\,000 = 18\,000 + 2000\,(v_{fmbus})$

$22\,000 = 2000\ v_{fmbus}$

v_{fmbus} = 11 m·s^{-1}

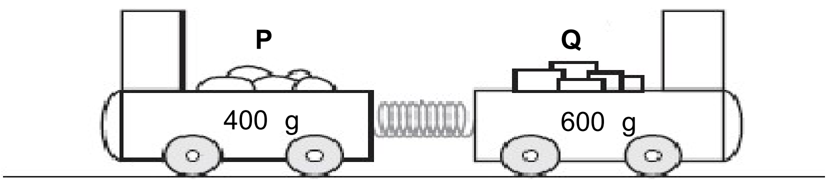
∴ v_{fmbus} = 11 m.s^{-1} to the left.

1.3 The driver will continue moving forward at the same velocity as the minibus until the driver strikes the dashboard or windscreen.

1.4 A body will remain in its state of rest or motion at constant velocity unless a non-zero resultant force acts on it.

QUESTION 2 (QUESTION 4 DBE Nov 2012)

The diagram below shows two trolleys, **P** and **Q**, held together by means of a compressed spring on a flat, frictionless horizontal track. The masses of **P** and **Q** are 400 g and 600 g respectively.



When tl length. Trolley **Q then** moves to the right at

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

2.2 Calculate the:

2.2.1 Velocity of trolley P after the trolley are released

2.2.2 Magnitude of the average force exerted by the spring on trolley **Q**

SOLUTIONS

2.2.2

OPTION 1	OPTION 2
$F_{net}\Delta t = \Delta p$ $F_{net}\Delta t = m\,(v_f - v_i)$ $F_{net}(0,3) = 0,6\,(4 - 0)$ $F_{net} = \frac{2,4}{0,3}$ $= 8$ N	$a = \frac{v_f - v_i}{t}$ $= \frac{4-0}{0,3}$ **= 13,33 m.s^{-2}** $F_{net} = m\,a$ $= (0,6)\,(13,33)$ $= 8$ N

1.8.1 Differences between Elastic Collision and Inelastic Collision

Elastic Collision	Inelastic Collision
• Momentum before collision is equal to Momentum after collision. $\boxed{\Sigma p_i = \Sigma p_f}$	• Momentum before collision is equal to Momentum after collision. $\Sigma_{pi} = \Sigma_{pf}$
• Total Kinetic Energy in Joule (J) before collision **IS EQUAL** to the Total Kinetic Energy in Joule(J) after collision. $\boxed{\Sigma E_{ki} = \Sigma E_{kf}}$	• Total Kinetic Energy in Joule (J) before collision is **NOT EQUAL** to the Total Kinetic Energy in Joule(J) after collision. $\boxed{\sum \mathbf{E_{ki}} \neq \sum \mathbf{E_{kf}}}$

WORKED OUT EXAMPLES

QUESTION 1

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 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 $m.s^{-1}$

SOLUTIONS

1.1 **Given data:**

For ball 1: m = 150 g (0,15 kg) $v_i = 2\ m \cdot s^{-1}$ $v_f = 1,5\ m \cdot s^{-1}$

For ball 2: m =150 g (0,15 kg) $v_i = 1,5\ m.s^{-1}$ $v_f = ?$

Let to the right be positive

$\Sigma p_i = \Sigma p_f$

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

$(0,15)(2) + (0,15)(-1,5) = (0,15)(-1,5) + (0,15)\ v_f$

$0,3 - 0,225 = -0,225 + 0,15\ v_f$

$0,075 + 0,225 = 0,15\ v_f$

$v_f = +2\ m \cdot s^{-1}$ **to the right**

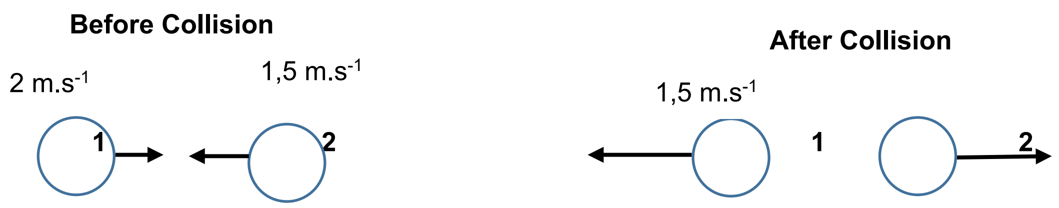
∴ velocity of ball 2 (v_{fb2}) is $2\ m \cdot s^{-1}$ **to the right**

NB:

- Always choose one direction as **Positive** or **Negative** (in this *problem/solution* 'to the right' is chosen as '**Positive**'.
- Always write the formula (Principle) correctly and fully before substituting the values.
- The final answer must have correct units.
- **Do not leave** the final answer with a Positive or Negative sign.
- **Always explain** the meaning of the negative or positive sign in the answer

1.1 Calculate the velocity of ball 2 after the collision

1.2 Prove that the collision was elastic. Show by means of calculation



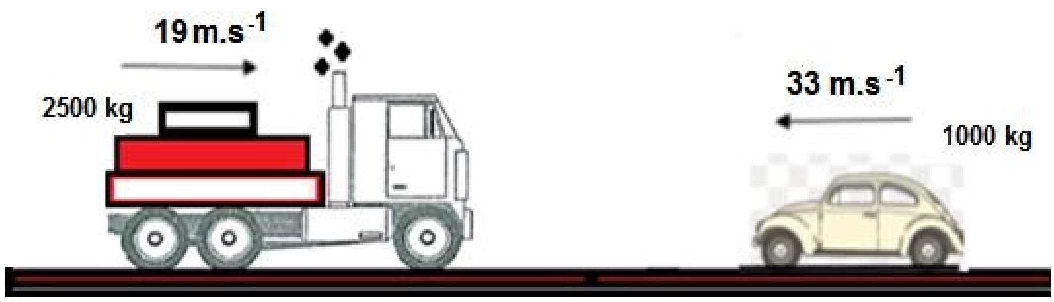
1.2

$\Sigma E_{ki} = (\frac{1}{2}mv^2)_1 + (\frac{1}{2}mv^2)_2$ = $(0,5)(0,15)(2)^2 + (0,5)(0,15)(-1,5)^2$ = 0,3 + 0,169 **= 0,469 J**	$\Sigma E_{kf} = (\frac{1}{2}mv^2)_1 + (\frac{1}{2}mv^2)_2$ = $(0,5)(0,15)(-0,5)^2 + (0,5)(0,15)(2)^2$ = 0,169 + 0,3 **= 0,469 J**
$\Sigma E_{ki} = \Sigma E_{kf}$, therefore the collision is elastic	

NB: TIPS ON PROVING WHETHER THE COLLISION IS ELASTIC OR INELASTIC	
• First calculate separately the sum of initial Kinetic Energy (**ΣE_{ki}**) and the sum of final Kinetic Energy (**ΣE_{kf}**) for objects involved. • Compare the final answers and make a conclusion, if,:	
	➢ **$\Sigma E_{ki} = \Sigma E_{kf}$**, the collision is elastic. ➢ **$\Sigma E_{ki} \neq \Sigma E_{kf}$** , the collision is inelastic.

QUESTION 2 (QUESTION 3 NW September 2019)

2.1 A car of mass 1 000 kg travels west with a velocity of 33 m·s^{-1} and collides head on with a truck of mass 2 500 kg that travels with a velocity of 19 m·s^{-1} due east. After the collision, the car and the truck move together respectively.



2.2.1 State the **Principle of *Conservation of Linear Momentum*** in words.
2.2.2 Calculate the speed of the system immediately after the collision.
2.2.3 By means of calculations show whether the collision is *elastic* or *inelastic*?
2.2.4 The car was fitted with an airbag. Explain how the airbag reduces the fatal injuries on a driver.

SOLUTIONS

2.2.1 In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision

OR

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

2.2.2 **Given data**: For Truck: m = 2500 kg $v_i = 19\ m\cdot s^{-1}$

For Car: m=1000 kg $v_i = 33\ m\cdot s^{-1}$ $v_{f\ c+T}$ =?

Let to the East be positive

$\Sigma p_i = \Sigma p_f$

$\mathbf{m_T v_{1i} + m_c v_{2i} = (m_T + m_c) v_f}$

(2500) (19) + (1000) (-33) = (2500+1000) $\mathbf{v_f}$

$\frac{14500}{3500} = v_{fT+C}$

$\mathbf{v_{fT+C} = 4{,}14}\ m\cdot s^{-1}$ **East**

2.2.3

$\Sigma E_{ki} = (\frac{1}{2}mv^2)_T + (\frac{1}{2}mv^2)_C$ = (0,5) (2500) (19)^2 + (0,5) (1000)(-33)^2 = 995750 J	$\Sigma E_{kf} = \frac{1}{2}(mv^2)_T + (\frac{1}{2}mv^2)_C$ = (0,5) (2500) (4.14)^2+(0,5) (1000)(4,14)^2 = 222814,80 J
$\Sigma E_{ki} \neq \Sigma E_{kf}$ ∴ The collision is inelastic.	

2.2.4 When the airbag inflates during the collision the contact time of the passenger or driver with an airbag is longer than without airbag while the change in momentum remains the same. Thus the net force on the passenger or driver is reduced according to the equation $F_{net} = \frac{\Delta p}{\Delta t}$

MOMENTUM ACTIVITIES

INSTRUCTIONS TO LEARNERS

- Attempt these questions individually and on completion share and discuss your answers with your classmates.
- All questions to be answered in your activity exercise book NO loose papers.
- Consult with your teacher for assistance on any challenge(s) encountered in the activity.

QUESTION 1: Multiple Choice Questions

Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A-D) next to the question number (1- 1.20) in the ANSWER BOOK, e.g. 1.21 B.

1.1 In the equation $F_{net}\,\Delta t = \Delta p$, the product $F_{net}\Delta t$ represents …

A change in momentum
B impulse.
C force per unit time.
D rate of change of momentum (2)

1.2 A ball with a mass m, travelling West, hits a wall with a velocity of v. It bounces back with the same velocity.

	Contact time (Δt)	**Δp**	**F_{net}**
A	Decrease	Increase	Decrease
B	Increase	Remains constant	Decrease
C	Decrease	Remains constant	Remains constant
D	Remains constant	Decrease	Decrease

(2)

1.6 Two trolleys approach each other in a straight line at the SAME speed and collide. After the collision, they remain in contact and come to REST. Which one of the following statements is FALSE?

A The two trolleys have the same mass
B The total linear momentum remains constant
C The linear momenta of the two trolleys are different before collision
D The total linear momentum before the collision is greater than the total linear momentum after the collision. (2)

1.7 A moving body with mass **m** and velocity v has a linear momentum **p**. What is the linear momentum, in terms of **p**, of another moving body with a mass of **4 m** and velocity of $\frac{1}{2}v$?

A 8p
B 2p
C p
D $\frac{1}{2}p$ (2)

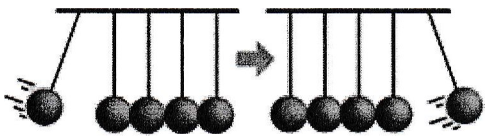
1.8 The front end of a modern car is designed to crumple in the case of a head-on collision. The chances of serious injuries to a passenger is reduced because the net force on the passenger is smaller since the …

A contact time between the passenger and inside of the car is decreased
B rate of the change in momentum is decreased.
C change in momentum is decreased.
D change in momentum is increased. (2)

1.9 Impulse is ...

A the same as momentum.
B the same as force
C determined by the change in momentum.
D independent from force. (2)

1.10 The photograph below demonstrates an elastic collision.



One ball One ball in One ball Out

Assuming that the system is ISOLATED, the conclusion is only CORRECT if the kinetic energy is …

A Conserved and the total energy of the system is conserved
B not conserved and the total energy of the system is conserved.
C conserved.
D not conserved and the total energy of the system is not conserved. (2)

1.11 A car experiences a constant net force of 500 N as it moves towards the west. The rate at which the momentum of the car changes during its motion is ...

A Equal to an impulse
B Equal to 500 N
C Greater than the net force
D Less than 500 N (2)

1.12 A ball with mass m strikes a wall with speed v. Assume that the collision is elastic. If the ball bounces back with the same speed v the magnitude of the change in momentum will be…

A 2 mv in the opposite direction
B mv in the opposite direction
C 2 mv in the original direction
D mv in the original direction (2)

1.13 The front end of a modern car is designed to crumple in the case of a head-on collision. The chances of serious injuries to a passenger is reduced because the net force on the passenger is smaller since the …

A contact time between the passenger and inside of the car is decreased
B rate of the change in momentum is decreased.
C change in momentum is decreased.
D change in momentum is increased. (2)

1.14 Impulse is ...
A the same as momentum.
B the same as force
C determined by the change in momentum.
D independent from force. (2)

1.15 Which one of the following best describes an inelastic collision?

A Both momentum and kinetic energy are conserved.
B Total kinetic energy is not conserved but total linear momentum is conserved.
C Neither kinetic energy nor momentum are conserved
D Kinetic energy is conserved but the total momentum is not conserved. (2)

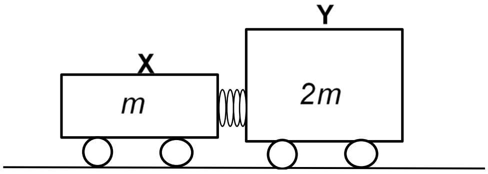
1.16 A car experiences a constant net force of 500 N as it moves towards the west. The rate at which the momentum of the car changes during its motion is ...

A Equal to an impulse
B Equal to 500 N
C Greater than the net force
D Less than 500 N (2)

1.17 The impulse acting on an object is equal to the … of the object.

A product of the mass and speed
B rate of change in momentum
C change in momentum
D acceleration (2)

1.18 Two trolleys, X and Y with masses m and 2m respectively, are held together with a compressed spring between them. Initially they are stationery on a horizontal floor as shown. Ignore the effects of friction.



The spring is now released and falls to the floor while the trolleys move apart. The magnitude of the MOMENTUM of trolley **X** is …

A the same as the magnitude of the momentum of trolley **Y.**
B twice the magnitude of the momentum of trolley **Y**
C half the magnitude of the momentum of trolley **Y**.
D zero. (2)

1.19 The impulse on an object is equal to the objects change in...

A Momentum
B Force
C Kinetic energy
D velocity (2)

1.20 The police patrol vehicle in the photograph below collided with a big truck. Forensic tests showed that the collision was inelastic.

Assuming that the system is ISOLATED, the conclusion is only CORRECT if the kinetic energy is…

A Conserved and the total energy of the system is conserved.
B Not conserved and the total energy of the system is not conserved.
C Not conserved and the total energy of the system is conserved.
D Conserved. (2)

STRUCTURED QUESTIONS

QUESTION 2 (QUESTION 3 EC Sept 2018)

A car of mass 800 kg travels due east with a velocity of 120 km.h^{-1} and collides head on with a construction truck of mass 2500 kg that travels with a velocity of 70 km.h^{-1} due west. After the collision, the car and the truck move together

2.1 Define ***momentum.*** (2)

2.2 State the ***Principle of Conservation of Momentum***. (2)

2.3 Calculate the velocity of the car and truck combination after the collision. (5)

2.4 The car is fitted with an airbag. Explain how the airbag reduces the fatal injuries on a driver. (3)

QUESTION 3 (QUESTION 4 EC June 2018)

A nail of mass 5 g is held horizontally and is hit with a hammer. The hammer exerts 7 N force on the nail and was in contact with the nail for 0,005 s

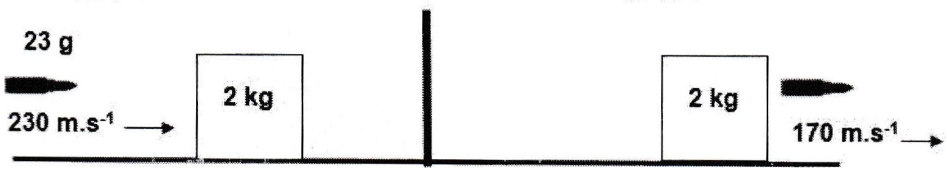
3.1 Define impulse. (2)

3.2 Calculate the impulse on the nail. (3)

3.3 Calculate the velocity of the nail after the blow. (4)

QUESTION 4 (QUESTION 5 EC June 2018)

A 23 g bullet travelling at 230 m·s^{-1} penetrates a 2 kg block of wood which is at rest on a frictionless surface. The bullet emerges cleanly at 170 m·s^{-1}. The collision is **inelastic**



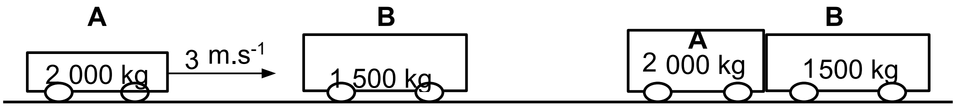
4.1 State the Principle of Conservation of Linear Momentum in words (2)

4.2 Calculate the velocity of the block of the block immediately after the bullet emerges from it (4)

4.3 Explain whether the kinetic energy is **CONSERVED** or **NOT CONSERVED** (2)

QUESTION 5 (QUESTION 3 FS JUNE 2019)

A railway truck **A**, mass 2 000 kg, moves eastwards at a velocity of 3 m·s^{-1}. It collides with a stationary truck **B**, mass 1 500 kg. The two trucks combine after the collision. Ignore the effects of friction.



5.1 Define the term **momentum** in words (2)

5.2 State the *Principle of Conservation of Linear Momentum* in words (2)

5.3 Calculate the VELOCITY of truck **B** after the collision (4)

5.4 Calculate the magnitude of the force that truck **A** exerts on truck **B** if the collision lasts for 0,5 s. (4)

5.5 The front and rear ends of railway trucks are fitted with thick rubber to reduce the damage during collisions. Explain how this is possible by referring to relevant scientific principles. (2)

QUESTION 6 (QUESTION 4 FS MARCH 2019)

A truck **T**, mass 3 600 kg, is travelling due EAST at 25 $m \cdot s^{-1}$ when it collides head on with a car **C**, overtaking a vehicle on a blind rise. The mass of the car is 800 kg. It was travelling at 35 $m \cdot s^{-1}$ due WEST at the moment of impact. After the collision, the two vehicles are so intertwined that the wreck moves together as one piece

6.1 Which conservation principle can we use to calculate the velocity of the wreck after the collision? (1)

6.2 Write down this principle in words. (2)

6.3 Calculate the velocity of the wreck immediately after the collision. (5)

6.4 Suppose that the 65 kg truck driver is NOT wearing his seat belt and the truck does not have a crumple zone. When the driver makes contact with the windscreen, it brings him to the same speed as the wreck in 0,005 s. Ignore any frictional forces on the driver.

6.4.1 Calculate the force exerted on the truck driver by the windscreen (4)

6.4.2 Without any further calculation, write down the magnitude of the force that the truck driver exerts on the windscreen. (1)

6.5 Distinguish between elastic and inelastic collisions. Refer to momentum and energy (4)

6.6 Head-on collisions are fatal most of the time. What may be the scientific reason for that? Briefly explain it in terms of force and velocity (2)

QUESTION 7 (QUESTION 3 FS SEPTEMBER 2019)

7.1 A hunting rifle of 3,6 kg fires a bullet with a mass of 8,4 g. The bullet leaves the barrel of the rifle at a speed of 914 $m \cdot s^{-1}$.

7.1.1 When we deal with the principle of the conservation of momentum, we refer to an isolated system. What does *isolate system* mean? (2)

An explosion like this one that takes place inside the chamber of the rifle, can be considered a special kind of 'collision' in physics.

7.1.2 Calculate the **VELOCITY** of the rifle at the instant the shot is fired. (4)

7.1.3 Will the MAGNITUDE of the velocity of the rifle be GREATER THAN, THE SAME AS or LESS, if a **HEAVIER** bullet is fired at the same velocity with the same rifle? (1)

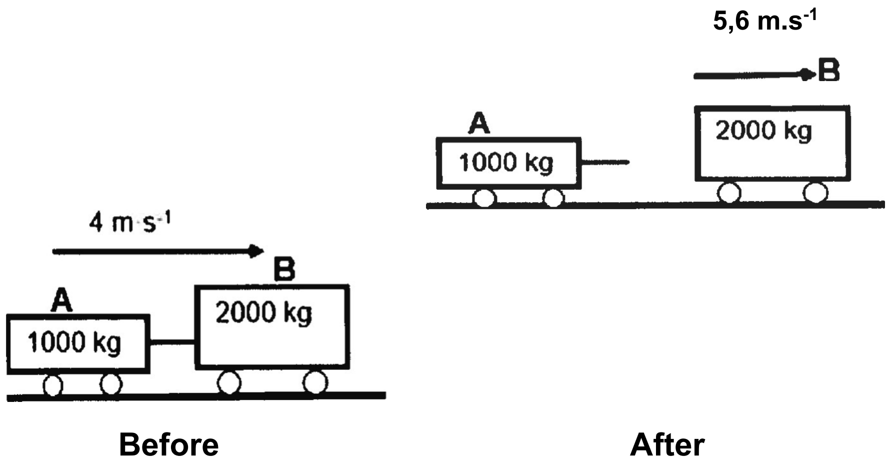
7.1.4 Is this 'collision' elastic or inelastic? (1)

7.1.5 Give a reason for your answer to QUESTION 3.1.4 and support your reason with the necessary calculation(s). (4)

7.2 A soccer ball, with a mass of 400 g, moves across a horizontal floor in a straight line at a speed of 4 $m \cdot s^{-1}$. It hits a wall and then it moves in the opposite direction at 3 $m \cdot s^{-1}$ directly after the collision. The ball is in contact with the wall for 0,14 s. Calculate the magnitude of the force that the wall exerts on the ball. (4)

QUESTION 8 (QUESTION 3 GP SEPTEMBER 2019)

Two train coaches, A and B, with masses of 1000 kg and 2 000 kg respectively are attached to each other with a compressed spring. They move to the right at 4 $m \cdot s^{-1}$ along a frictionless, horizontal railway track. When the spring is released, and it has expanded completely, the 2000 kg coach moves to the right at a velocity of 5,6 $m \cdot s^{-1}$ as shown in the diagram below.



8.1 State the Principle of Conservation of Linear Momentum in words (2)

8.2 Calculate the magnitude and direction of the velocity of the 1 000 kg coach immediately after the spring has expanded completely. (4)

8.3 If it takes 0,2 s for the spring to expand completely

8.3.1 Calculate the impulse of **Coach A** on **Coach B.** (3)

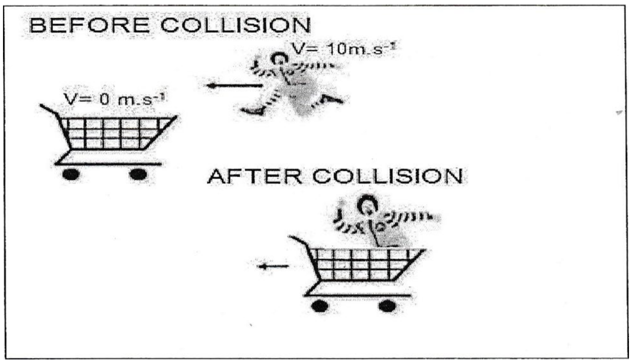
8.3.2 Calculate the average force exerted by Coach A on Coach B. (4)

8.4.1 How will the average force exerted by Coach A on Coash B be affected if the time taken for the spring to expand is increased to seconds. Write down only INCREASE, DECREASE or REMAIN THE SAME (1)

8.4.2 Explain your answer to **Question 8.4.1** (2)

QUESTION 9 (QUESTION 4 KZN MARCH 2019)

A clown with a mass of 80 kg is running at a constant velocity towards the left. While still running he observes a stationery cart of mass 30 kg ahead of him and when he is closer to the cart, he immediately jumps HORIZONTALLY into the cart at a velocity of 10 m·s^{-1}. The clown and the cart move together as a unit in a straight line towards the left after the collision



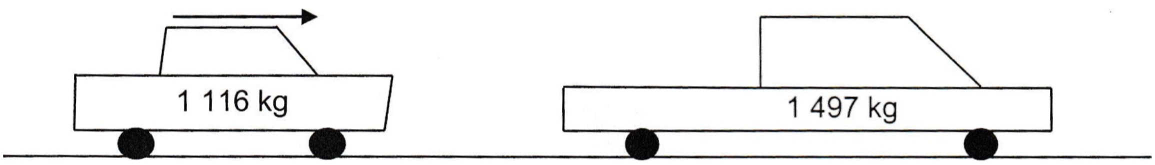
9.1 State the Principle of Conservation of Linear Momentum (2)

9.2 Calculate the combined velocity of the clown and the cart after collision (5)

9.3 Do necessary calculations to show that the collision was inelastic (6)

QUESTION 10 (QUESTION 4 DBE NOVEMBER 2019)

A car of mass 1 1 16 kg was travelling at 30 m·s^{-1} towards the east when it collided with a stationary bakkie of mass 1 497 kg. After the collision the bakkie moved at 8 m·s^{-1} to the east.



Assume that the system is isolated

10.1 Define the term ***Isolated System*** (2)

10.2 Calculate the momentum of the car just before the collision (3)

10.3 Determine the magnitude of the car's velocity after the collision (4)

10.4 Name and state the principle used to answer **Question 10.3** (3)

10.5 Without calculation, determine how the final momentum of the car compares with the initial momentum. Write only GREATER THAN, SMALLER THAN or EQUAL TO. (1)

10.6 Explain your answer to **QUESTION 10.5** (2)

QUESTION 11 (QUESTION 5 DBE NOVEMBER 2019)

A construction vehicle hit a container of mass 80 kg which was stationery on a frictionless floor. The vehicle exerted a force of 4,5 kN over 3 $X10^{-2}$ s on the container. The collision between the vehicle and the container was INELASTIC.

11.1 Explain the concept **INELASTIC COLLISION**

11.2 Define (net) force in terms of momentum

11.3 Calculate the velocity of the container after the collision

QUESTION 12 (QUESTION 5 FS MARCH 2020)

The diagram below shows Thabo running on a horizontal floor and jumps onto a stationary 1,3 kg skateboard. The skateboard and Thabo combination moves forward at a speed of 3,5 $m \cdot s^{-1}$. Thabo's mass is 37 kg. Ignore the effects of friction.

12.1 Is momentum a vector or a scalar quantity? Explain (2)

12.2 Define the term ***isolated system*** in science (2)

12.3 Name AND state a principle that can be used to calculate Thabo's speed BEFORE he jumps onto the skateboard. (3)

12.4 Use the principle you have mentioned in **Question 12.3** and calculate Thabo's speed before he jumps onto the skateboard. (4)

12.5 Is the magnitude of THABO's FINAL momentum **GREATER THAN**, THE SAME AS or LESS THAN the magnitude of HIS INITIAL momentum? (1)

12.6 Explain your answer to **Question 12.5**. (1)

QUESTION 13 (QUESTION 6 FS MARCH 2020)

A hunting rifle fires a bullet horizontally to the LEFT. The bullet leaves the barrel of the rifle at a speed of 965 $m \cdot s^{-1}$. Due to this, the momentum of the rifle is 4,05 $kg \cdot m \cdot s^{-1}$ to the RIGHT.

13.1 Calculate the mass of the bullet in kilogram. (5)

13.2 Convert the mass of the bullet to gram. (1)

QUESTION 14 (QUESTION 7 FS MARCH 2020)

A man, mass 80 kg and wearing a seat belt, is driving a car which collides with the back of a stationary truck causing the car to come to rest in 0,2 s. Just before the collision, the car is travelling at 20 $m \cdot s^{-1}$.

14.1 Calculate the force exerted by the seat belt on the man. (4)

14.2 The front ends of modern cars are deliberately designed to crumple in head-on collisions in order to minimise injuries. Refer to science principles and briefly explain why this design minimise injuries. Support your answer with a relevant equation. (4)

QUESTION 15 (QUESTION 4 KZN MARCH 2020)

15.1 A cricket ball of mass 163 g is bawled towards a batman at a speed of 29 $m \cdot s^{-1}$. The batsman misses the ball, and the wicketkeeper catches the bal.

15.1.1 Calculate the magnitude of the average force exerted by the wicketkeeper on the ball, if he stops the ball in 0,3 s (5)

15.1.2 Explain by using a scientific equation, why the wicketkeeper should pull his hands back when catching a fast-moving cricket ball. (3)

QUESTION 16 (QUESTION 3 DBE/2018 – Exemplar)

16.1 During a crash test a car of mass $1,5 \times 10^3$ kg collides with a wall and comes to rest within 0,15 s. The initial velocity of the car is 12 $m \cdot s^{-1}$ to the left.

Calculate the :

16.1.1 Impulse exerted by the wall on the car (3)

16.1.2 Magnitude of the average force exerted on the car during the collision (3)

16.2 On a railway shunting line a locomotive of mass 6000 kg, travelling due east at a velocity of 1,25 $m \cdot s^{-1}$, collides with a stationery goods wagon of mass 4500 kg in an attempt to couple with it. The coupling fails and instead the goods wagon moves due east at a velocity of 2,5 $m \cdot s^{-1}$.

16.2.1 State the ***Principle of Conservation of Linear Momentum*** in words. (2)

16.2.2 Calculate the magnitude and direction of the velocity of the locomotive immediately after the collision. (5)

16.2.3 Show with calculation whether this collision is elastic or inelastic. (7)

QUESTION 17 (QUESTION 3 FS JUNE 2019

17.1 A baseball of mass 0,145 kg is thrown to a baseball player at a velocity of 49,17 $m \cdot s^{-1}$. The baseball player hits the ball back towards the bowler at a velocity of 31,39 $m \cdot s^{-1}$.

17.1.1 Define the term ***Impulse*** (2)

17.1.2 How will the impulse of the ball on the bat be affected when the velocity at which the ball returns towards the bowler is increased to a value greater than 31,39 $m\cdot s^{-1}$? Write only **INCREASES, DECREASES** or **REMAINS CONSTANT**. (2)

17.1.3 Will the net force exerted by the ball on the bat **INCREASE** or **DECREASE** when the time of contact between the ball and the bat increases? Give a reason for your answer. (Assume Δp remains constant.) (3)

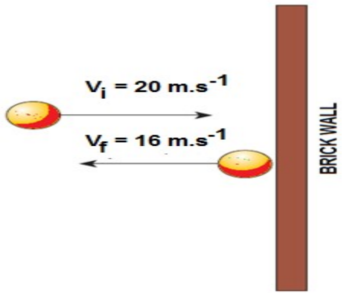
17.1.4 Calculate the net force exerted by the bat on the ball when the contact time between the bat and the ball is 0,007 s (4)

17.1.5 What is the magnitude and direction of the net force exerted by the ball on the bat? (2)

17.1.6 Name and state the law used to answer **QUESTION 17.1.5** (3)

QUESTION 18 (QUESTION 3 NW SEPTEMBER 2019)

18.1 Study the diagrams below which show a 150 g tennis ball strikes a wall at 20 $m\cdot s^{-1}$ and bounces back in the opposite direction at 16 $m\cdot s^{-1}$. The tennis ball is thrown at a wall at right angle.



18.1.1 Define the term ***Impulse*** in words (2)

18.1.2 Calculate the impulse on the ball (4)

MOMENTUM POSSIBLE SOLUTIONS AND MARKING GUIDELINES

QUESTION 1: MULTIPLE CHOICE QUESTIONS

1.1 B ✓✓	1.2 D ✓✓	1.3 A ✓✓	1.4 A ✓✓	1.5 B ✓✓
1.6 D ✓✓	1.7 D ✓✓	1.8 B ✓✓	1.9 C ✓✓	1.10 A ✓✓
1.11 B ✓✓	1.12 A ✓✓	1.13 B ✓✓	1.14 C ✓✓	1.15 A ✓✓
1.16 B ✓✓	1.17 A ✓✓	1.18 B ✓✓	1.19 C ✓✓	1.20 A ✓✓
1.21 A ✓✓	1.22 D ✓✓			

STRUCTURED QUESTIONS POSSIBLE ANSWERS

QUESTION 2

2.1 Is the product of mass and velocity of an object ✓✓ (2)

2.2 In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision ✓✓

OR

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

(2)

2.3 **Given data**:

For the car: m = 800 kg v_i = 120 km.h^{-1} (33,33 m.s^{-1} East)

Truck: m = 2500 kg v_i = 70 km.h^{-1} (19.44 **m·s^{-1}** West)

Let East be positive

$\Sigma p_i = \Sigma p_f$

$m_C v_i + m_T v_i = (m_c + m_t)\, v_{fc\text{-}t}$ ✓ Any one

$(800 \times 33{,}33)$ ✓ $+ (2500 \times 19{,}44)$ ✓ $= (800 + 2500)\, v_{fct}$ ✓

$2666{,}40 - 48600 = 3300\, v_{fct}$

$v_{fct} = -\,13{,}92$ m·s^{-1}

∴ v_{fct} **13,92 m·s^{-1} West** ✓ (5)

2.4 When the airbag inflates during the collision the contact time of the driver with an airbag is longer✓ than without airbag while the change in momentum remains the same. ✓ Thus the net force on the driver is reduced according to the equation $F_{net} = \frac{\Delta p}{\Delta t}$ ✓ (3)

QUESTION 3

3.1 Impulse is the product of the net force acting on an object and the time the net force acts on an object. ✓✓ (2)

3.2 $\text{Impulse} = F_{net}\Delta t$ ✓
$= (7)(0{,}005)$ ✓
$= \mathbf{0{,}035\ N.s}$ ✓ (3)

3.3 **POSITIVE MARKING FROM 3.2**
OPTION 1:

$F_{net}\Delta t = \Delta p$
$F_{net}\Delta t = m(v_f - v_i)$ ✓ any one
$0{,}035$ ✓ $= 0{,}005\ (v_f - 0)$ ✓

(convert **g** to **kg**: $\frac{5}{1000} = 0{,}005\ kg$

$\mathbf{v_f = 7\ m.s^{-1}}$ ✓

OPTION 2:

$F_{net} = ma$ ✓
$7 = (0{,}005)\ a$ ✓
$a = 1400\ m.s^{-2}$

$v_f = v_i + at$
$= 0 + (1400)(0{,}005)$ ✓
$= \mathbf{7\ m.s^{-1}}$ ✓ (4)

QUESTION 4

4.1 In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision ✓✓

OR

The total linear momentum of an isolated system remains constant in magnitude and direction ✓✓ (2)

4.2 **Let to the right be positive**
$\Sigma p_i = \Sigma p_f$
$m_B v_{iB} + m_{bl} v_{bli} = m_B v_{fB} + m_{bl} v_{blf}$ ✓ any one
(0,023)(230) + (2)(0) ✓ = (0,023)(170) + (2) v_{blf} ✓
$\mathbf{v_{blf} = 0.69\ m\cdot s^{-1}}$ **to the right** ✓ (4)

4.3 Kinetic energy is not conserved therefore the collision is inelastic ✓✓ (2)

QUESTION 5

5.1 The product of the mass and velocity of an object ✓✓ (2)

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

OR

In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision ✓✓ (2)

5.3

OPTION 1: (Let East be positive)	**OPTION 2: (Let East be negative)**
$\left.\begin{array}{l}\Sigma p_i = \Sigma p_f \\ m_A v_i + m_B v_i = (m_A + m_B) v_f\end{array}\right\}$ ✓ anyone $(2000)(3) + (1500)(0)$ ✓ $=(2000+1500)\ v_f$ ✓ $6000 = 3500\ v_f$ $v_f = 1,71\ m\cdot s^{-1}$ $\therefore$ **$v_f = 1,71\ m\cdot s^{-1}$ East** ✓	$\left.\begin{array}{l}\Sigma p_i = \Sigma p_f \\ m_A v_i + m_B v_i = (m_A + m_B) v_f\end{array}\right\}$ ✓ anyone $(2000)(-3) + (1500)(0)$ ✓ $=(2000+1500)\ v_f$ ✓ $-6000 = 3500\ v_f$ $v_f = -1,71\ m\cdot s^{-1}$ $\therefore$ **$v_f = 1,71\ m\cdot s^{-1}$ East** ✓

(4)

5.4 $F_{net}\Delta t = \Delta p$ ✓

$F_{net}(0,5)$ ✓ $= 1500\ (1,71 - 0)$ ✓

$F_{net} = 5130$ N ✓ (4)

5.5 According to the formula, $F_{net} = \frac{\Delta p}{\Delta t}$, ✓ the thick rubber increases time (Δt) ✓, when Δp remains constant✓, thus decreasing F_{net} ✓ (4)

QUESTION 6

6.1 Principle of Conservation of Linear Momentum ✓ (1)

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

OR

In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision ✓✓

(2)

6.3

OPTION 1: Let East be positive	Option 2: Let East be negative
$\Sigma p_i = \Sigma p_f$ $m_T v_i + m_C v_i = (m_T + m_C)\, v_f$ ✓any one (3600) (25) ✓+ (800)(-35) ✓= (3600 +800) v_f ✓ 90000 -28000 = 4400 v_f **v_f = 14,09 m.s^{-1} East** ✓	$\Sigma p_i = \Sigma p_f$ $m_T v_i + m_C v_i = (m_T + m_C)\, v_f$ ✓ any one (3600) (-25) ✓+ (800)(35) ✓= (3600 +800) v_f ✓ -90000 + 28000 = 4400 v_f v_f = -14,09 m.s^{-1} ∴ **v_f = 14,09 m.s^{-1} East** ✓

(5)

6.4.1 **POSITIVE MARKING FROM 6.3**

OPTION 1: Let East be positive	OPTION 2: Let East be negative
$F_{net}\Delta t = \Delta p$ ✓ $F_{net}(0{,}005)$✓= (65 x 14,09) –(65x 25) ✓ $F_{net} = \frac{-709{,}15}{0{,}005}$ F_{net} = -141830 N ∴ **F_{net} = 141830 N West** ✓	$F_{net}\Delta t = \Delta p$ ✓ $F_{net}(0{,}005)$✓= (65 x (-14,09) –(65x -25) ✓ $F_{net} = \frac{709{,}15}{0{,}005}$ F_{net} = 141830 N ∴ **F_{net} = 141830 N West** ✓

(4)

6.4.2 **POSITIVE MARKING FROM 6.4.1**
141830 N ✓ (1)

6.4.3 Newton's Third Law of Motion ✓ (1)
When object **A** exerts a force on object **B**, object **B** simultaneously exerts an oppositely directed force of equal magnitude on object **A**. ✓✓ (2)

6.5

Elastic Collision	Inelastic Collision
• Momentum is conserved. ✓ • Kinetic energy is conserved✓	• Momentum is conserved. ✓ • Kinetic energy is **NOT** conserved✓

(4)

6.6 During head on collision the time taken(Δt) by colliding objects is shorter whilst the velocity is high✓, and Δp is not constant thus increasing the net force which in turn results to fatalities. ✓ (2)

QUESTION 7

7.1.1 The net external forces on the system is zero ✓✓ (2)

7.1.2 Let bullet direction be positive / Let to the right be positive

$\Sigma p_i = \Sigma p_f$
$(m_{Ri}+m_{Bi})(v_{RB}) = (m_R \times v_{Rf})+(m_B \times v_{Bf})$ ✓ anyone
$(3{,}6 + 0{,}0084)(0)$ ✓ $= (3{,}6 \times v_{Rf}) + (0{,}0084 \times 914)$ ✓
$0 = 3{,}6\, v_{Rf} + 7{,}68$
$v_{Rf} = -2{,}13$
$\therefore v_{Rf} =$ **2,13 m.s⁻¹ to the left** ✓ (4)

7.1.3 Greater than ✓ (1)
7.1.4 Inelastic ✓ (1)

7.1.5 **Positive marking from 7.1.2**

$E_{ki} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$ ✓ $= \frac{1}{2}(3{,}6)(0)^2 + \frac{1}{2}(0{,}0084)(0)^2$ ✓ $= 0$ J	$\Sigma E_{kf} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$ $= \frac{1}{2}(3{,}6)(2{,}13)^2 + \frac{1}{2}(0{,}0084)(914)^2$ ✓ **= 3516,83 J**
$E_{ki} \neq E_{kf}$ ∴ the collision is inelastic ✓	

7.2

OPTION 1: Let to the wall be Positive	OPTION 2: Let to the wall be Negative
$F_{net}\Delta t = \Delta p$ $F_{net} = \frac{m(v_f - v_i)}{\Delta t}$ ✓ any one $= \frac{0{,}4(-3-(4)}{0{,}14}$ ✓ ✓ $= -20$ N ∴ the wall exerts 20 N ✓	$F_{net}\Delta t = \Delta p$ $F_{net} = \frac{m(v_f - v_i)}{\Delta t}$ ✓ any one $= \frac{0{,}4(3-(-4)}{0{,}14}$ ✓ $= 20$ N ∴ the wall exerts 20 N ✓

(4)

QUESTION 8

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

OR

In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision ✓✓

(2)

8.2 Let to the right be positive

$\Sigma p_i = \Sigma p_f$ ✓ any one

$(m_{Ai}+m_{Bi})(v_{ABi}) = (m_A v_{Af}) + (m_B v_{Bf})$

$(1000 + 2000)(4)$ ✓ $= 1000\, v_{Af} + (2000)(5,6)$ ✓

$12000 = 1000\, v_{Af} + 11200$

$v_{Af} = 0,8$ **m·s⁻¹** to the right ✓ (4)

8.3.1 **Coach A Impulse:**

Impulse $= \Delta p$ ✓

$= m\,(v_f - v_i)$

$= 1000\,(0.8 - 4)$ ✓

$= -3200$

$= 3200$ kg. **$m\cdot s^{-1}$** to the left✓ (3)

8.3.2 $F_{net}\Delta t = \Delta p$ ✓

$F_{net}\,(0,2)$ ✓$= 3200$✓

$F_{net} = 16000$ N✓ (4)

8.4.1 Decrease

8.4.2 The increase in the time of impact decreases F_{net}.

OR

F_{net} is inversely proportional to time, according to $F_{net} = \frac{\Delta p}{\Delta t}$ (2)

QUESTION 9

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

OR

In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision ✓✓

(2)

9.2 **Let to the Left be positive**

$\Sigma p_i = \Sigma p_f$ ✓ any one

$(mv_{icl}) + (mv_{icart}) = (m_{cl} + m_{cart})\,(v_{fcl+cartf})$

$(80)\,(10)$ ✓$+ (30)(0)$ ✓ $= (80 + 30)\,(v_{fcl+cartf})$ ✓

$800 + 0 = (110)\,v_{fcl+cartf}$

$v_{fcl+cartf} = 7,27$ **$m\cdot s^{-1}$ to the left** ✓

(5)

9.3

$\Sigma E_{ki} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$ ✓ $= \frac{1}{2}(80)(10^2) + \frac{1}{2}(30)(0^2)$ ✓ $= 4000$ J ← $\boxed{✓}$	→ $= 2906,91$ J $\Sigma E_{kf} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$ ✓ $= \frac{1}{2}(80)(7,27^2) + \frac{1}{2}(30)(7,27^2)$ ✓
$\Sigma E_{ki} \neq \Sigma E_{kf}$ ∴therefore the collision is inelastic ✓	

QUESTION 10

10.1 An isolated system is the one in which the net external force acting on the system is zero ✓✓

OR

External net force is equal to zero ✓✓ (2)

10.2 Let East be positive

$p_{car} = mv$ ✓

$= 1116 \times 30$ ✓

$= 33480$ **kg.m·s^{-1}** East✓ (3)

10.3 Let East be positive

$$\left.\begin{aligned} \Sigma p_i &= \Sigma p_f \\ m_c v_{ic} + m_B v_{iB} &= m_c v_{fc} + m_B v_{fB} \end{aligned}\right\} \text{✓ any one}$$

$\underline{(1116)(30) + (1497)(0)}$ ✓ $= \underline{(1116)\, v_{fc} + (1497)(8)}$ ✓

$v_{fc} = 19,27$ m.s^{-1} East ✓ (4)

10.4 Principle of Conservation of Linear Momentum

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

OR

In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision ✓✓ (3)

10.5 Smaller than ✓ (1)

10.6 Velocity of the car decreased after collision from 30 m.s^{-1} to 19,27 m·s^{-1}

Momentum is directly proportional to the velocity ✓✓ (2)

QUESTION 11

11.1
- Total linear Momentum is conserved✓
- Total kinetic energy is not conserved ✓ (2)

11.2 The net force is equal to the rate of change in momentum✓✓ (2)

11.3

$$\left.\begin{aligned} F_{net}\Delta t &= \Delta p \\ F_{net}\Delta t &= m(v_f - v_i) \end{aligned}\right\} \text{✓ any one}$$

$(4,5 \times 10^3)(3 \times 10^{-2})$ ✓ $= 80\,(v_f - 0)$ ✓

$v_f = 1,69$ m·s^{-1} in the direction of motion ✓ (4)

QUESTION 12

12.1 Vector quantity ✓
Has magnitude and direction ✓ (2)

12.2 Net external force is zero ✓✓ (2)

12.3 Principle of Conservation of Momentum ✓
The total linear momentum of an isolated system remains constant (in magnitude and direction). ✓✓

OR

In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision ✓✓
(3)

12.4 $\Sigma p_i = \Sigma p_f$

$m_T v_{iT} + m_s v_{is} = (m_T + m_s) v_f$
$37\ v_{iT} + (1{,}3)(0)$ ✓ $= (37 + 1{,}3)3{,}5$ ✓ ✓ any one
$37\ v_{iT} = 134{,}05$
v_{iT} = 3,62 m·s^{-1} in the original direction ✓ (4)

12.5 Less than ✓ (1)

Velocities are not the same $v_i = 3{,}62 m.s^{-1}$ and $v_f = 3{,}5 m.s^{-1}$ but mass is constant.
m = 37 kg ✓ (1)

QUESTION 13

13.1 Let to the Left be positive
$\Sigma p_i = \Sigma p_f$ ✓ Any one
$(m_G + m_s) v_f = m_G v_{Gf} + m_B v_{Fb}$
0 ✓ = 4,05 + (- 965) m_B ✓
-4,05 = -965m_B
m_B = **0,0042 kg** or **4,2 x10^{-3} kg** ✓ (4)

13.2 0,0042 kg: 0,0042 x 10^3 = 4,2 g ✓

OR

0,0042 x 1000 = 4,2 g ✓ (1)

QUESTION 14

14.1 **Option 1**

Let original direction be positive

$F_{net}\Delta t = \Delta p$

$F_{net}\Delta t = m(v_f - v_i)$ ✓

F_{net} (0,2) ✓ = 80 (0-20) ✓

$F_{net} = \frac{-1600}{0,2}$

=- 8000 N

= 8000 N in the opposite direction ✓

Option 2

Let original direction be positive

$a = \frac{v_f - v_i}{t}$

$a = \frac{0-20}{0,2}$ ✓

$a = -100\ ms^{-2}$

$F_{net} = ma$

= (80)(-100) ✓

= - 8000 N

= 8000 N in the opposite direction✓

(4)

14.2 From $F_{net} = \frac{\Delta p}{\Delta t}$ ✓,Crumpling increases contact time✓, when change in momentum (Δp) remains constant✓, thus reducing the net force✓. (4)

QUESTION 15

15.1 Let towards the wicketkeeper be positive

$F_{net}\Delta t = \Delta p$

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

F_{net} (0,3) ✓ = (0,163 x 0) ✓ +(0,163 x- 29) ✓

$F_{net} = \frac{-4,73}{0,3}$

= -15,76 N

∴ F_{net}= 15,76 N away from the wicketkeeper ✓

(5)

15.2 According to the equation, $F_{net}\Delta t = \Delta p$✓ , by moving his hands backwards he increases the contact time (Δt) ✓ but keeping change in momentum (Δp) constant ,the F_{net} is decreased thus reducing injuries to his hands. ✓ (3)

QUESTION 16

16.1.1 Impulse = Δp

=m $(v_f - v_i)$ ✓any one

= (1,5 x10³ x 0)- (1,5 x10³ x 12) ✓

= -18000 kg. m·s^{-1}

∴ Impulse = **18000 kg. m·s^{-1} to the right** ✓

(3)

16.1.2 $F_{net}\Delta t = \Delta p$ ✓

F_{net} (0,15) = 18000

$F_{net} = \frac{18000}{0,15}$ ✓

= **120000 N** or **1,2 x 10⁵ N** or **120 kN** ✓ (any one)

(3)

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

OR

In an isolated system the total linear momentum before collision is equal to the total linear momentum after collision ✓✓

(2)

16.2.2 **Let East be positive**

$$\left.\begin{array}{l}\Sigma p_i = \Sigma p_f \\ m_{LC}v_i + m_{Gw}v_i = m_{LG}v_{lcf} + m_{wG}v_{fb}\end{array}\right\}\ \checkmark \text{ any one}$$

$(6000 \times 1,25)$ ✓ + (4500×0) ✓= $6000 \times v_{lcf} + 4500 \times 2,5$ ✓

$7500 + 0 = 6000\, v_{lcf} + 11250$

$-3750 = 6000\, v_{lcf}$

v_{lcf} = -0,625 m·s^{-1} West ✓

(5)

16.2.3

$$\Sigma E_{ki} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 \longleftarrow \boxed{\checkmark} \longrightarrow \Sigma E_{kf} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$$

$$= \frac{1}{2}(6000)(1,25)^2 + \frac{1}{2}(4500)(0)^2 \ \checkmark$$

$$= 4687,50 + 0$$

$$= 4687,50 \text{ J} \ \checkmark$$

$$= \frac{1}{2}(6000)(-0,625)^2 + \frac{1}{2}(4500)(2,5)^2 \checkmark$$

$$= 1171,88 + 14062,88$$

$$= 15234,76 \text{ J} \ \checkmark$$

(7)

$\Sigma E_{ki} \neq \Sigma E_{kf}$, therefore the collision is inelastic ✓✓

QUESTION 17

17.1.1 Is the product of the net force (acting on an object) and the time the net force (acts on the object) ✓✓

OR

Is equal to the change in momentum✓✓ (2)

17.1.2 Increases ✓✓ (2)

17.1.3 Decrease✓

- From Impulse-momentum theorem, it follows that net force ✓exerted on an object is inversely proportional to the contact time✓

OR

- From Impulse-momentum theorem, it follows that when contact time ✓ increases the net force decreases✓

(3)

17.1.4 **OPTION 1**

Let towards the batsman be positive

$$\left.\begin{array}{l}F_{net}\Delta t = \Delta p \\ F_{net}\Delta t = m\,(v_f - v_i)\end{array}\right\}\ \checkmark \text{ any one}$$

$F_{net}\,(0,007)$ ✓ $= 0.145\,(-31,39 - (+49,17))$ ✓

$F_{net} = -\,1668,71$ N

$F_{net} = 1668,71$ N away from the batsman✓

OPTION 1

Let towards the batsman be negative

$$\left.\begin{array}{l}F_{net}\Delta t = \Delta p \\ F_{net}\Delta t = m\,(v_f - v_i)\end{array}\right\}\ \checkmark \text{ any one}$$

$F_{net}\,(0,007)$ ✓ $= 0.145(-31,39 - (+49,17))$ ✓

$F_{net} = -\,1668,71$ N

$F_{net} = 1668,71$ N away from the batsman✓

17.1.5 1668,71 N towards the batsman✓✓

17.1.6 Newton's Third Law of Motion✓

- When object A exerts a force on object B, object be simultaneously exerts an oppositely directed force of equal magnitude on object A. ✓✓ (3)

QUESTION 18

18.1.1 Impulse is the product of the net force acting on an object and the time the net force acts on the object. ✓✓ (2)

18.1.2 Let towards the ball be positive.

$$\left.\begin{aligned}\text{Impulse} &= \Delta p \\ &= m(v_f - v_i)\end{aligned}\right\} \checkmark \text{ any one}$$

$$= 0{,}15 \checkmark (-16 - 20) \checkmark$$

$$= -5{,}4 \text{ kg.ms}^{-1}$$

$$= 5{,}4 \text{ kg.ms}^{-1} \text{ away from the wall } \checkmark$$ (4)

3. WORK, ENERGY AND POWER

Chapter Summary

WORK, ENERGY AND POWER

Work

$W = F\Delta x\cos\theta$

SI unit: joule(J)

Energy

SI unit: joule(J)

Power

$P = \frac{W}{\Delta t}$

SI unit: watt (W)

Kinetic energy (E_k)

$E_K = \frac{1}{2}mv^2$

Mechanical energy (E_M)

$E_M = E_k + E_P$

SI unit: joule(J)

Power and velocity

$P = Fv$

V =constant velocity

Gravitational Potential energy (E_p)

$E_p = mgh$

Law of conservation of mechanical energy

$(E_k + E_p)_i = (E_k + E_p)_f$

CHAPTER THREE: WORK,ENERGY AND POWER

3. WORK

3.1 What is Work?

- Is the product of the force applied on an object and the displacement in the direction of the force.
- is a scalar quantity (has magnitude only)
- a negative value of work indicates energy loss.
- a positive value of work indicates gain in kinetic energy.
- Work done on an object can be calculated using the following formula:

$$\boxed{W = F\Delta x \cos\theta}$$

where: W = work done in joules (J)

F = magnitude of the force in newton (N)

Δx = displacement in metres (m)

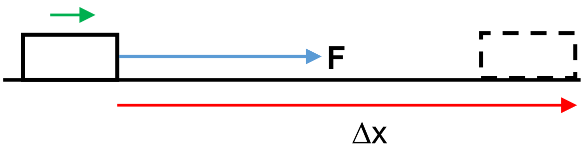
θ = is the angle in degrees (°), between the force F) and the displacement of the object Δx

3.2 Positive, Zero and Negative work

Consider the scenarios illustrated below:

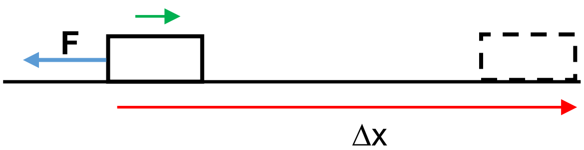
The object is moving to the right as indicated by an arrow.

3.2.1 When the force and displacement are parallel to each other and point in the same direction the angle (θ) is 0°



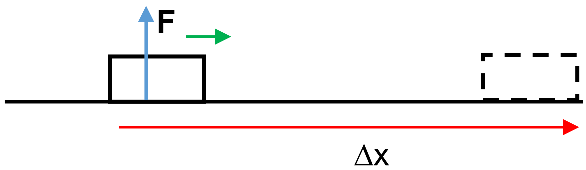
The work done by the force is positive, the angle is less than 90°.

3.2.2 When the force and displacement are parallel to each other but point in opposite directions the angle (θ) is 180°



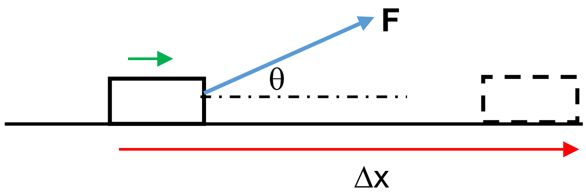
The work done by the force is negative, the angle is greater than 90°

3.2.3 When the force and displacement are perpendicular to each other the angle (θ) is 90°



The work done by the force is ZERO, because cos 90° is 0.

3.2.4 When the force is applied at an angle with the horizontal as shown below. The angle between the force and the displacement is equal to the given angle.



The work done by the force is positive, the angle is less than 90°.
The work done by the force is equal to the work done by the horizontal component ($W_F = W_{Fx}$).

3.3 TIPS ON ANSWERING QUESTIONS BASED ON WORK

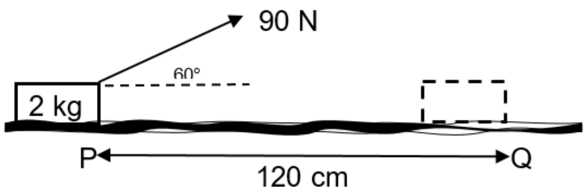
- Read the given statement with understanding and list the data.
- Determine the direction of the displacement.
- Draw a labelled force or free-body diagram indicating all the forces acting on the object.
- Determine the angle measured from the direction of the displacement to each force.
- Copy the formula as given in the formula sheet.
- Make a direct substitution of the given data.
- Write the final answer with correct units.

3.4 CONVERSION FACTORS

- 1 kg = 1000 g (to convert mass from g to kg divide by 1000).
- 1 m = 100 cm (to convert from cm to m divide by 100).
- To convert speed/velocity from $km \cdot h^{-1}$ to $m \cdot s^{-1}$ divide by 3,6.
- 1 kW = 1000 W (to convert from kW to W multiply by 1000).
- 1 Horse power (hp) = 746 W (to convert from hp to W we multiply by 746).

Worked example.

1. A force of 90 N is exerted at an angle of 60° on a 2 Kg object and causes the object to move a distance of 120 cm to the right from point P to Q on the horizontal rough surface.



The magnitude of the frictional force between the surface and the object is 20 N.

1.1 Define term *work* in words. (2)

1.2 Convert 120 cm to metres. (1)

1.3 Draw a labelled free-body diagram indicating ALL the forces acting on the object whilst in motion. (4)

1.4 Calculate the work done by the:

1.4.1 Applied force. (3)

1.4.2 Frictional force. (3)

1.4.3 Gravitational force. (3)

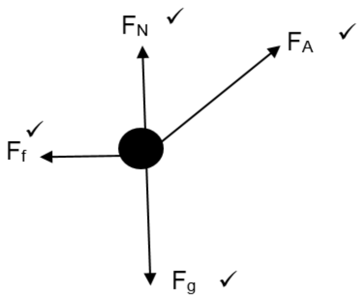
1.4.4 What is the work done by the Normal force? Give a reason for the answer. (2)

Solutions

1.1 is the product of the force applied on an object and the displacement in the direction of the force. ✓✓ (2)

1.2 $\Delta x = \frac{120}{100} = 1{,}2\ m$ ✓ (1)

1.3



(4)

1.4.1 $W = F\,\Delta x \cos\theta$ ✓

W = (90)(1,2)cos60° ✓

W = 54 J (3)

1.4.2 $W = F_f \Delta x \cos\theta$ ✓

$W = (20)(1,2)\cos 180°$ ✓

$W = -24$ J ✓ (3)

1.4.3 $W = F_g \Delta x \cos\theta$ ✓

$W = (2 \times 9,8)(1,2)\cos 90°$ ✓

$W = 0$ J ✓ (3)

1.4.4 ZERO (O J) ✓, the normal force is perpendicular to the displacement and cos90° is ZERO. (3)

2. ENERGY

2.1 What is energy?

- Is the ability to do work.
- Is a scalar quantity (has magnitude only)
- It is measured in joules (J)

2.2 FORMS OF ENERGY

- Kinetic energy (E_k)
- Gravitational potential energy (E_p)
- Mechanical energy (E_M)

2.2.1 Kinetic energy (E_k)

- is the energy of an object due to its motion.
- formula to calculate kinetic energy is:

$$\boxed{E_K = \frac{1}{2}mv^2}$$

Where:

E_k = Kinetic energy in joules (J).

m = mass of the object in kilograms (kg)

v = speed/velocity in metres per second ($m \cdot s^{-1}$)

2.2.2 Gravitational potential energy (E_P)

- is the energy of an object due to its position from the surface of the earth.
- formula to calculate gravitational potential energy is:

$$\boxed{E_p = mgh}$$

Where:

E_p = Gravitational potential energy in joules (**J**).
m = mass of the object in kilograms (kg)
g = gravitational acceleration in metres per second square (**9,8 m·s^{-2}**)
h = height in metres (**m**)

2.2.3 **Mechanical energy (E_M)**

- is the sum of the kinetic and gravitational potential energy of an object.
- formula to calculate the mechanical energy is:

$$\boxed{E_M = E_k + E_p}$$

Where:

E_M = mechanical energy in joules (J)
E_k = Kinetic energy in joules (J).
E_p = Gravitational potential energy in joules (J).

2.2.4 **Law of conservation of mechanical energy.**

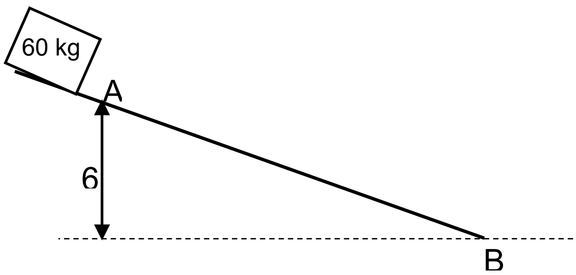
- *The law of conservation of mechanical energy states that the **total mechanical energy** of an i**solated system** is constant.*
- An **isolated system** is one in which the net external force is zero.

NB:
- The initial mechanical energy is equal to the final mechanical energy

$$\boxed{(E_k + E_p)_i = (E_k + E_p)_f}$$

2.3 **Worked example.**

A box of mass 60 kg slides down a frictionless inclined surface as shown in the diagram below. The box reaches point A at a speed of 5 m·s^{-1} which is 6 m above the horizontal



Calculate at point A the:

2.3.1	Kinetic energy of the box	(3)
2.3.2	Gravitational potential energy of the box.	(3)
2.3.3	Mechanical energy of the box.	(3)
2.3.4	What is the mechanical energy of the object at point B? Give a reason of the answer.	(2)
2.3.5	Use the law of conservation of mechanical energy to calculate the speed of the box at point B.	(4)

Solutions

2.3.1 $E_K = \frac{1}{2}mv^2$ ✓

$E_K = \frac{1}{2}(60)(5)^2$ ✓

$E_K = 750\ J$ ✓ (3)

2.3.2 $E_p = mgh$ ✓

$E_p = (60)(9,8)(6)$ ✓

$E_p = 3\ 528\ J$ ✓ (3)

2.3.3 $E_M = E_k + E_p$ ✓

$E_M = 750 + 3\ 528$ ✓

$E_M = 4\ 278\ J$ ✓ (3)

2.3.4 E_M = 4 278 J ✓, because the system is isolated (E_M initial = E_M final) ✓ (2)

2.3.5 $(E_k + E_p)_i = (E_k + E_p)_f$ ✓

$4\ 278$ ✓ $= \frac{1}{2}mv^2 + mgh$

$4\ 278 = \frac{1}{2}(60)v^2 + (60)(9,8)(0)$ ✓

$v = 11,94\ m \cdot s^{-1}$ ✓ (4)

3. POWER

3.1 What is power?

- Is the rate at which work is done.
- Is a scalar quantity.
- Is measured in watts (W).
- The formula to calculate power is:

$$\boxed{P = \frac{W}{\Delta t}}$$

Where:

P = power in watt (W).
W = Work done in Joule (J).
Δt = Change in time in second (s).

3.2 Power and velocity

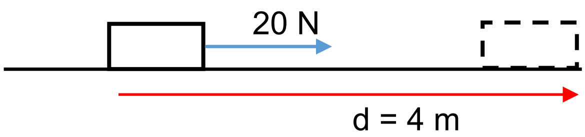
- When the object is moving at a constant speed/velocity the relationship between power and velocity is given by:

$$\boxed{P = Fv}$$

Where: P = power in watt (W).
F = force in newton (N).
v = constant speed/velocity ($m{\cdot}s^{-1}$)

3.3 Worked example

A force of 20 N is applied on an object to move the object a distance of 4 m in 5 s to the right on a frictionless surface as shown in the diagram below.



Calculate the:

3.3.1 Work done by the force. (3)
3.3.2 Power (3)

Solutions

3.3.1 $W = F\,\Delta x \cos\theta$ ✓

$W = (20)(4)\cos 0°$ ✓

$W = 80\ J$ ✓ (3)

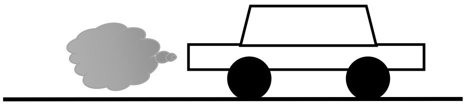
3.3.2 $P = \frac{W}{\Delta t}$ ✓

$P = \frac{80}{5}$ ✓

$P = 16\ W$ ✓ (4)

3.4 **Worked example 2**

A car delivers a power of 2 hp whilst moving at a constant speed of 30 $m{\cdot}s^{-1}$.



3.4.1 Convert the power from hp to W. (1)

3.4.2 Calculate the magnitude of the force exerted by the engine on the car. (4)

Solutions

3.4.1 $1\ hp = 746\ W$

$2\ hp = ?$

$P = 2 \times 746$

$= 1\ 492\ W$ ✓ (1)

3.4.2 $P = Fv$ ✓ (4)

$1\ 492$ ✓ $= F(30)$ ✓

$F = 49{,}73\ N$ ✓

[5]

Work, Energy and Power Activities

QUESTION 1: MULTIPLE CHOICE QUESTIONS

Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A-D) next to the question number (1.1-1.16) in the ANSWER BOOK, e.g. 1.17 D.

1.1 Which ONE of the following quantities is NOT a vector?
- A Force
- B Displacement
- C Velocity
- D Work (2)

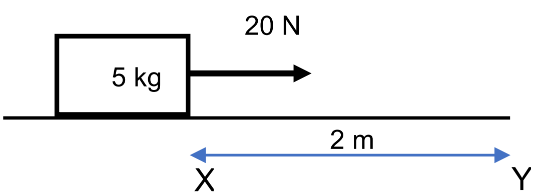
1.2 Which ONE of the following unit is equivalent to Joule (J)?
- A N.s
- B $kg{\cdot}m{\cdot}s^{-1}$
- C $kg{\cdot}m^2{\cdot}s^{-2}$
- D W (2)

1.3 The rate at which work is done is…
- A Power
- B Work
- C Energy
- D Momentum (2)

STRUCTURAL QUESTIONS

QUESTION 2

2.1 A horizontal force of 20 N is applied on a box of 5kg which is resting on a frictionless horizontal surface.



2.1.1 Draw a free body diagram showing all the forces acting on the box. (3)
2.1.2 Calculate the weight of the box. (3)
2.1.3 Write down the magnitude of the normal force acting on the box. (1)

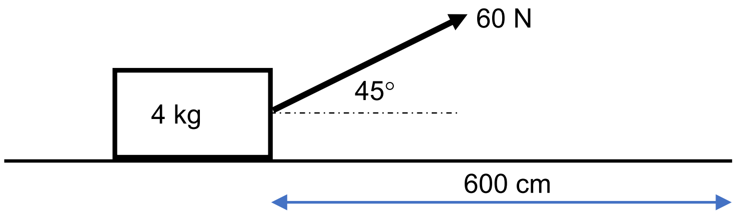
The following questions are based on the diagram in **Question 2.1** above.

2.2 The box moves a distance of 2 m from point **X** to point **Y**.

2.2.1 Define the term work done. (2)
2.2.2 Calculate the work done by the 20 N force on the box as it moves from **X** to **Y**. (3)
2.2.3 Write down the magnitude of the work done by the normal force. (1)

QUESTION 3

A force of 60 N is applied on a box of 4 kg at an angle of 45° to the horizontal. The box moves a distance of 600 cm over a frictionless surface.



3.1 Draw a free body diagram showing all forces acting on a box. (3)

3.2 Calculate the:

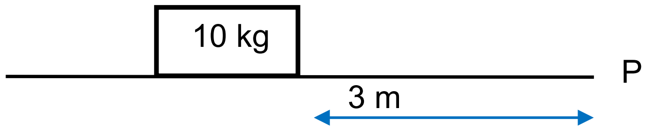
3.2.1 Horizontal component of the 60 N force. (2)

3.2.2 Work done by the applied force when moving the box for 600 cm. (3)

3.3 Force of gravity does a zero-work on the box. Give a reason for the answer. (2)

QUESTION 4

4.1 A box of mass 10 kg, is sliding over a rough horizontal surface to the right for 3 m and stops at point P. The frictional force between the box and the surface is 9 N.



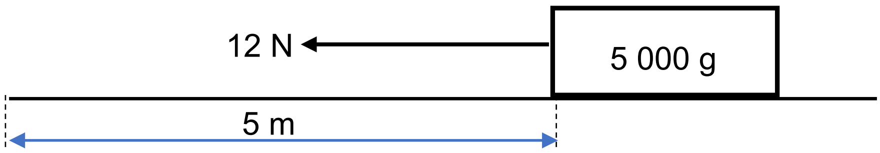
4.1.1 Define the term frictional force. (2)

4.1.2 Draw a labeled free body diagram showing all forces acting on the box (3)

4.1.3 Calculate the work done by friction on the box. (3)

QUESTION 5

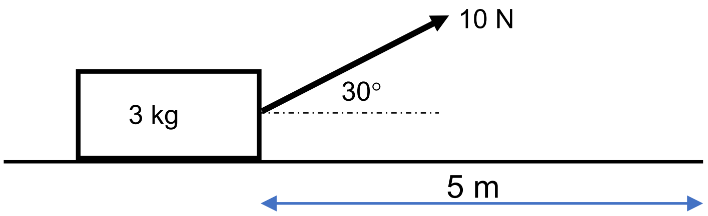
A box of mass 5000 g is pulled with a constant horizontal force of 12 N over a horizontal surface to the left. The frictional force between the surface and the box is 5 N.



5.1 Define the term resultant force (2)
5.2 Draw a labeled free body diagram showing all forces acting on the box. (4)
5.3 Determine the resultant force of all the forces acting on the box. (2)
5.4 Calculate the work done by the:
  5.4.1 Applied force. (3)
  5.4.2 Frictional force. (3)

QUESTION 6

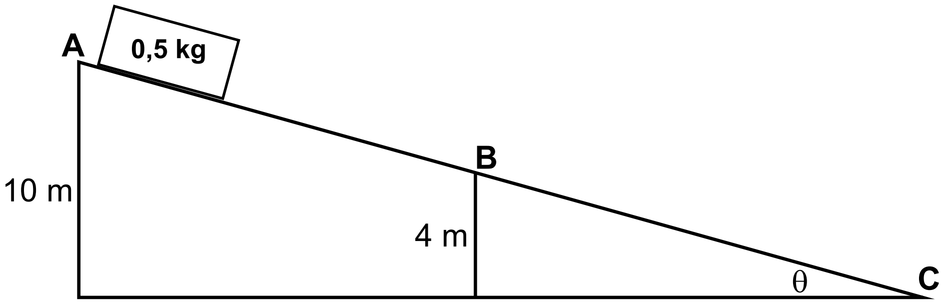
A box of a mass 3 kg is pulled with a force of 10 N which act at an angle of 30° to the horizontal. The frictional force between the surface and the box is 3 N.



6.1 Draw a labeled free body diagram showing all forces acting on the box. (4)
6.2 Determine the resultant force of all forces acting on a box. (3)
6.3 Calculate the:
  6.3.1 Vertical component of the applied force. (3)
  6.3.2 Normal force. (3)
  6.3.3 Work done by the applied force. (3)
  6.3.4 Work done by the frictional force. (3)
  6.3.5 Work done by the normal force. (3)
6.4 What is the work done by the gravitational force? Give a reason for the answer. (2)

QUESTION 7

A box of mass 0,5 kg is released from the top of an inclined frictionless surface at point A from a height of 10 m above the ground.



7.1 State the principle of conservation of mechanical energy in words. (2)

7.2 Calculate the:

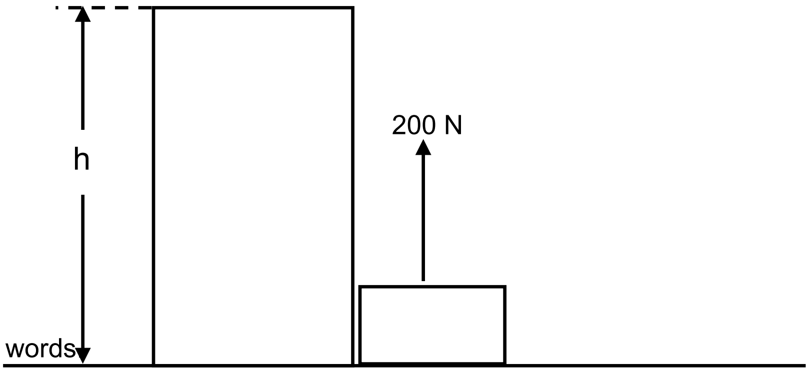
7.2.1 Potential energy before the ball was released. (3)

7.2.2 Kinetic energy of the ball when it is at point B. (4)

7.2.3 Speed of the ball when it reaches the bottom of the ramp at point C. (4)

Question 8

A box is pulled up from the bottom of the building with a height, **h** by applying a force of 200 N and the box moves with a constant speed of 2 $m \cdot s^{-1}$



8.1 Define the term power in words. (2)

8.2 Calculate the power generated to lift the box to the top of the building. (4)

8.3 If the box took 5 seconds to reach the top of the building calculate:

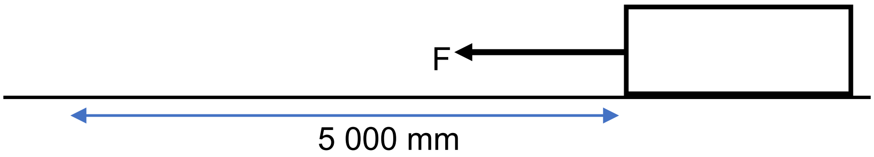
8.3.1 Height (h) of the building. (4)

8.3.2 The work done by the applied force on lifting the box to the top of the building. (4)

Question 9

9.1 A trolley is pulled by a constant horizontal force F to the left as shown in the diagram below. The trolley accelerates at 2 m·s^{-2}. The frictional force between the surface and the trolley is 3 N

.



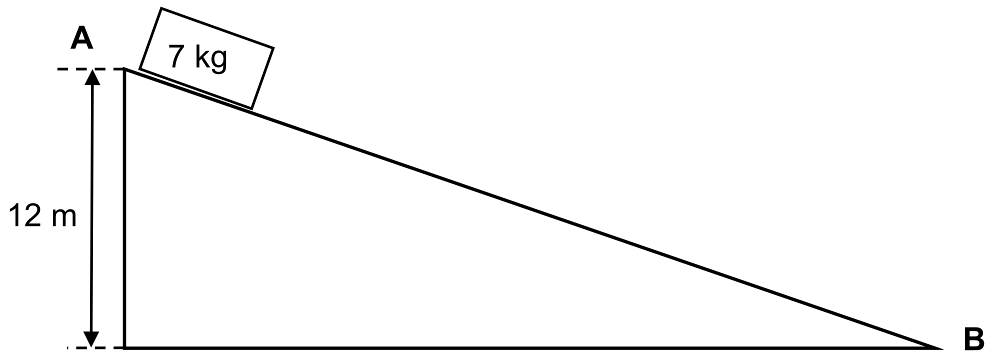
. The work done by force, F on the trolley when it moves for 5000 mm is 40 J, calculate:

9.1.1 The magnitude of force F. (5)

9.1.2 The mass of the trolley. (4)

Question 10

A box of mass 7 kg is released at point **A** from the height of 12 m above the ground and slides down the frictionless inclined surface. The box reaches the bottom at point **B** of the incline at a speed of 9 m·s^{-1}.



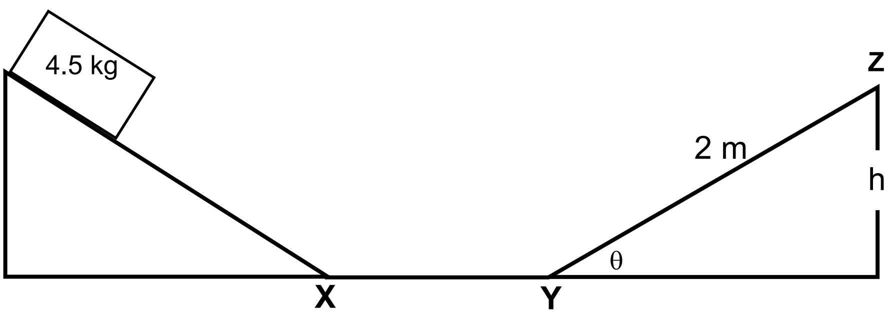
10.1 State the principle of conservation of mechanical energy in words. (2)

10.2 Is the mechanical energy of the box conserved between point **A** and **B**? Write down only **YES** or **NO**. Use a suitable calculation to justify the answer. (5)

10.3 Calculate the energy lost through friction. (2)

Question 11

A box slides down the frictionless inclined surface. At the bottom of the inclined surface the speed of the box is 3 m·s^{-1} at point X. The ball reaches another frictionless inclined surface at point **Y** which make an angle,θ, with the horizontal.it slides up the surface for a distance of 2 m and stop.



11.1 What is the speed at point Y? Give the reason for the answer. (2)

11.2 Calculate the:

- 11.2.1 Mechanical energy of the box at point Y. (3)
- 11.2.2 Height (h) using the conservation of mechanical energy. (4)
- 11.2.3 Angle (θ). (3)

WORK,ENERGY AND POWER: RESPONSES TO QUESTIONS

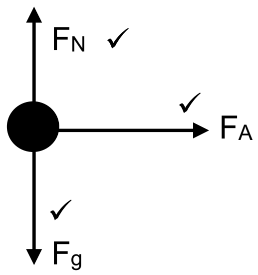
QUESTION 1: MULTIPLE CHOICE SOLUTIONS

1.1 D ✓✓ (2)
1.2 C ✓✓ (2)
1.3 A ✓✓ (2)

SOLUTIONS: STRUCTURED QUESTIONS

QUESTION 2

2.1.1



(3)

2.1.2 $F_g = mg$ ✓
$= (5)(9,8)$ ✓
$= 49\ N$ ✓

2.1.3 $F_N = 49\ N$ ✓ (1)

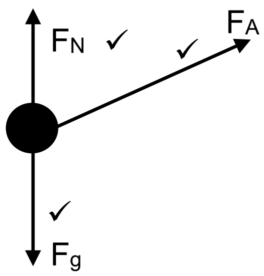
2.2.1 Product of a force and the displacement in the direction of the force.✓✓ (2)

2.2.2 $W = F_A \Delta x \cos\theta$ ✓ (3)
$= (20)(2)(\cos 0°)$✓
$= 40J$ ✓

2.2.3 $0\ J$ ✓ (ZERO) (1)

QUESTION 3

3.1



(3)

3.2.1 $F_x = F\cos\theta$ ✓

$= (60)\cos 45°$ ✓

$= 42,43$ N ✓ (3)

3.2.2 $W = F\Delta x\cos\theta$ ✓

$= (60)(6)\cos 45°$ ✓

$= 254{,}56$ J ✓

(3)

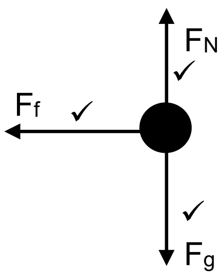
3.3 The force is perpendicular to the displacement /the angle between the force and displacement is 90° and cos 90° is 0.✓✓

(2)

QUESTION 4

4.1.1 Force parallel to the surface that opposes the motion of object and acts in the direction opposite to the motion of an object.✓✓ (2)

4.1.2



(3)

4.1.3 $W = F_k \Delta x \cos\theta$ ✓

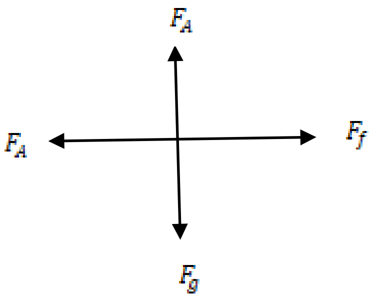
$= (9)(3)\cos 180°$ ✓

$= -27$J ✓ (3)

QUESTION 5

5.1 Is the sum of two or more forces acting on the object.✓✓ (2)

5.2



(4)

5.3 $F_{net} = F_A + F_k$

$= 12 + (-5)$ ✓

$= 7$ N to the left ✓ (2)

5.4.1 $W = F_A \Delta x \cos\theta$ ✓

$W = (12)(5)\cos 0°$ ✓

$W = 60$ J ✓ (3)

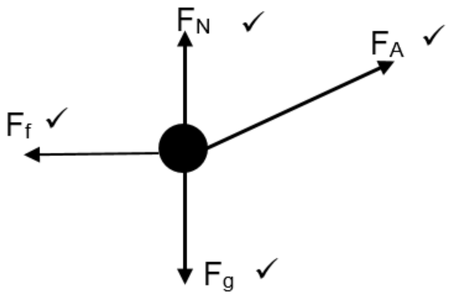
5.4.2 $W = F_k \Delta x \cos\theta$ ✓

$= (5)(5)\cos 180°$ ✓

$= -25J$ ✓ (3)

QUESTION 6

6.1



(4)

6.2 $F_{net} = F_x + F_k$ ✓

$F_x = F\cos 30$

$= 10x\cos 30$

$= 8.66$ N

$F_{net} = 8.66 + (-3)$ ✓

$= 5.66$ N ✓ (3)

6.3.1 $F_y = F\sin\theta$ ✓

$F_y = (10)\sin 30°$ ✓

$F_y = 5$ N upwards ✓

(3)

6.3.2 $F_N = mg - F_y$ ✓

$F_N = (3)(9{,}8) - 5$ ✓

$F_N = 24{,}4$ N ✓

(3)

6.3.3 $W = F_A \Delta x \cos\theta$ ✓

$= (10)(5)\cos 30°$ ✓

$= 43{,}30$ J ✓

(3)

6.3.4 $W = F_k \Delta x \cos\theta$ ✓
$= (3)(5)\cos 180°$ ✓
$= -15 J$ ✓ (3)

6.3.5 $W = F_N \Delta x \cos\theta$ ✓
$= (24,4)(5)\cos 90°$ ✓
$= 0 J$ ✓

(3)

6.4 0 J ✓, the force is perpendicular to the displacement. ✓ (2)

QUESTION 7

7.1 The total mechanical energy (sum of gravitational potential energy and kinetic energy) in an isolated system remains constant.✓✓ (2)

7.2.1 $E_p = mgh$ ✓
$= (0.5)(9.8)(10)$ ✓
$= 49 J$ ✓ (3)

7.2.2 $E_k + E_p = E_M$ ✓
$E_p = mgh$
$= 0.5 \times 9.8 \times 4$ ✓
$= 19.6 J$
$E_k + 19.6 = 49$ ✓ (4)

$E_k = 29.4 J$ ✓

7.2.3 $E_k + E_p = E_M$ ✓
$\frac{1}{2}(0,5)v^2 + 0$ ✓ $= 49$ ✓
$v = 14 m \cdot s^{-1}$ ✓ (4)

QUESTION 8

8.1 Is the rate at which work is done ✓✓ (2)

8.2 P = FV ✓
= (200)(2) ✓
= 400 W ✓ (3)

8.3.1 **OPTION 1**

$v = \frac{\Delta y}{\Delta t}$ ✓
$2 = \frac{\Delta y}{5}$ ✓
$\Delta y = 10 m$ ✓

OPTION 2

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓
$\Delta y = (2)(5) + \frac{1}{2}(0)(5)^2$ ✓
$\Delta y = 10 m$ ✓

(3)

8.3.2 **Option 1**

$P = \frac{W}{\Delta t}$ ✓

$400 = \frac{W}{5}$ ✓

$W = 2000\ J$ ✓

Option 2

$W = F_A \Delta x \cos\theta$ ✓

$= (200)(10)\cos 0°$ ✓

$= 2000\ J$ ✓

(3)

QUESTION 9

9.1.1 $W = F_A \Delta x \cos\theta$ ✓

$40 = F_A (5)\cos 0°$ ✓

$F_A = 8\ N$ ✓ (3)

9.1.2 $F_{net} = ma$ ✓

$F + (-f) = ma$

8 ✓ $+ (-3)$ ✓ $= m(2)$ ✓

$m = 2.5\ kg$ ✓ (5)

QUESTION 10

10.1 The total mechanical energy (sum of gravitational potential energy and kinetic energy) in an isolated system remains constant.✓✓ (2)

10.2 No ✓

$(E_M)_A = E_k + E_p$ ✓

$= \frac{1}{2}mv^2 + mgh$

$= 0 + (7)(9{,}8)(12)$ ✓

$= 823{,}2\ J$

$(E_M)_B = E_k + E_p$

$= \frac{1}{2}mv^2 + mgh$

$= (\frac{1}{2})(7)(9)^2 + 0$ ✓

$= 283{,}5\ J$

$\therefore (E_M)_A \neq (E_M)_B$ ✓ (5)

10.3 $E_{lost} = (E_M)_A - (E_M)_B$

$= 823.2 - 283.5$✓

$= 539,7$ J✓ (2)

QUESTION 11

11.1 3 m·s^{-1}✓ (1)

11.2.1 $(E_M)_B = E_k + E_p$ ✓

$= \frac{1}{2}mv^2 + mgh$

$= (\frac{1}{2})(4.5)(3)^2 + 0$✓

$= 20,25$ J✓ (3)

11.2.2 $(E_M)_A = (E_M)_A$

$(E_k + E_p)_Y = (E_k + E_p)_Z$

$(\frac{1}{2}mv^2 + mgh) = (\frac{1}{2}mv^2 + mgh)$ ✓

$20,25 + 0$✓ $= (\frac{1}{2}(4,5)(0)^2 + (4,5)(9,8)h$✓

$h = 0,46$ m✓ (4)

11.2.3 $\sin\theta = \frac{0.46}{2}$ ✓

$\theta = 13,3^0$✓ (2)

ELASTICITY

The property of a body by virtue of the body regains its original shape and size when the deforming force is removed.

DEFORMING FORCE: A force that changes the shape and size of a body.

RESTORING FORCE: Develops inside the body and tries to bring the body back to its initial size and shape.

PERFECTLY ELASTIC BODY: A body which regains its original shape and size completely when the deforming force is removed; e.g a **rubber band**

PERFECTLY PLASTIC BODY: A body that does not show a tendency to regain its original size and shape when the deforming body is removed; e.g. **a plastic ruler.**

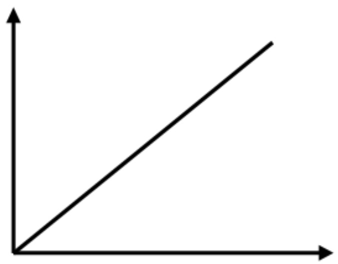
STRESS: The internal restoring force per unit area. $\boldsymbol{\sigma = \frac{F}{A}}$

STRAIN: The ratio of change in the dimension of an object to the original. $\boldsymbol{\varepsilon = \frac{\Delta l}{L}}$

Young's Modulus of Elasticity**.** $\boldsymbol{K = \frac{\sigma}{\varepsilon}}$

Hooke's Law

Within the limit of elasticity, stress is directly proportional to strain.



CHAPTER 4 : ELASTICITY

4.1 **ELASTICITY (**of a body): is the **property** of a body to **regain its original shape and size** when the **deforming force** is removed.

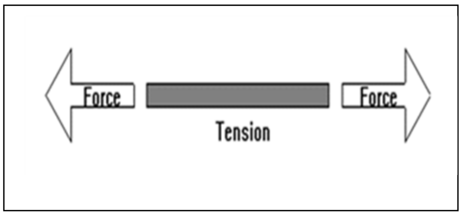
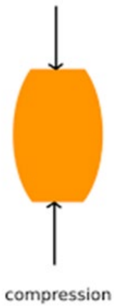
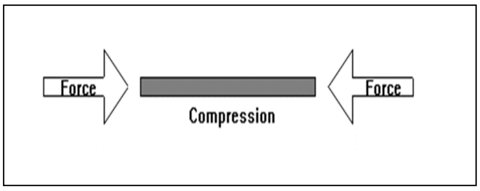
Effects of Force on an object **(Grade 8-9 Technology work)**

Effect of Force	Practical example
• Can cause a stationery object to move • Can stop a moving object • Can change the direction of a moving object • Can change the shape or size of an object	• Kicking a stationery object • Catching a cricket ball • Tennis players playing tennis • Squeezing a stress ball

4.2 DEFORMING FORCE

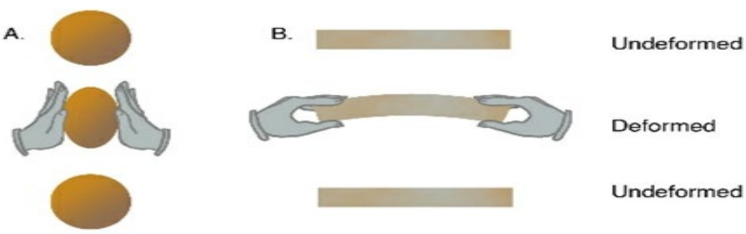
- is the force that **changes the shape and size** of a body.
- can be **tension force** or **compression force.**

4.2.1 Difference between Tension Force and Compression Force

Tension Force	Compression Force
• Pulls an object apart. • Stretches the body (increases the length of an object)	• Compresses an object. • Decreases the length and size of an object
Examples  	**Examples:**  

4.3 Restoring Force

- is the force that is equal and opposite to the deforming force applied to a body.
- restores the original shape and size of an object after the deforming force is removed



4.4 **A Perfectly elastic body:**

- is the body which regains its original **shape and size** completely when the deforming force is removed.

Examples:

			
Elastic bands	Trampoline	Springs	Spring diving board

4.5 **Perfectly Plastic Body**

- A body that **does not** show a tendency to **regain its original shape and size** when the deforming force is removed
- Consider the illustration below:

		
Before deforming force is applied-the object is its **original shape** and **size.**	During the application of deforming force- **shape** and **size** of the object is **changed.**	Deforming force is **removed**-object **does not regain** its **original shape** and **size.**

4.6 **Elastic limit**

- is the maximum force that can be applied to a body so that the body regains its original form completely on removal of the force.
- Consider the illustrations below:

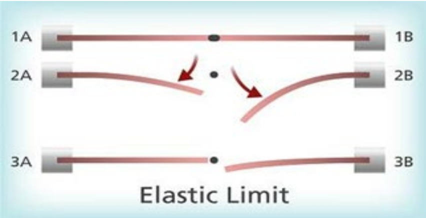


Illustration 1

- At **1A-1B**: Tension force is applied and the object is stretched and it will regain its original shape and size when the deforming force is removed- The object is still **within** its ELASTIC LIMIT.
- At **2A-2B**: The object can no longer regain its original shape and size.
- At **3A-3B**: The object has **exceeded** its Elastic Limit and it is broken-(will never regain its shape and size when the deforming force is removed).

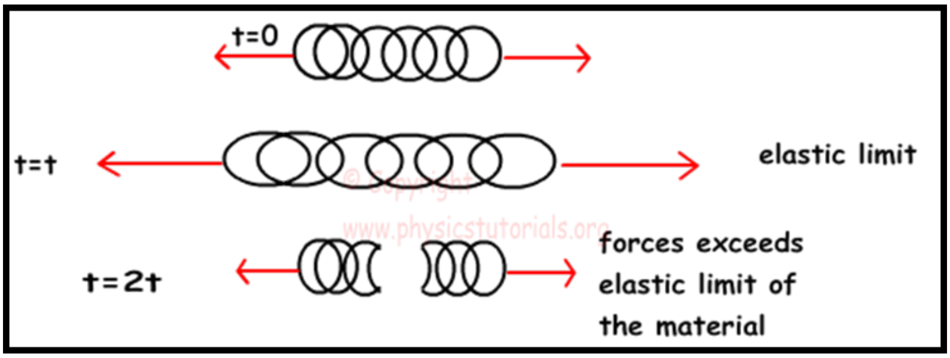


Illustration 2

4.7 **Stress (σ)**

- is the internal restoring force per unit area of a body.
- can be calculated using the formula:

$$\boxed{\sigma = \frac{F}{A}}$$

where:

σ (Sigma) = stress in Pascal **(Pa)**
F = Force in Newton **(N)**
A = Area of a body in square metre **(m^2)**

- SI unit: **Pa** (Pascal) or **$N^{\cdot}m^{-2}$** (Newton square metre)

4.8 Strain (ε)

- is the ratio of change in dimension to the original dimension
- can be calculated using the formula:

$$\boxed{\varepsilon = \frac{\Delta l}{L}}$$

where

ε (Epsilon) = Strain

Δl = change in dimension/length **(m)**

L = original dimension/length **(m)**

- Has **NO** SI units.

4.9 Hooke's Law

- ***Hooke's law*** states that, within the limit of elasticity, stress is directly proportional to strain

- Mathematical relationship:

$$\boxed{\sigma \ \alpha \ \varepsilon}$$

- For calculations the above relationship becomes:

$$\boxed{K = \frac{\sigma}{\varepsilon}}$$

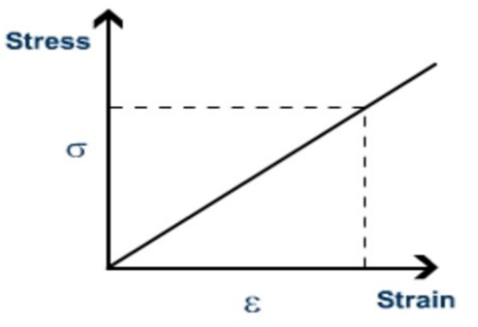
where:

σ = Stress in Pa (Pascal) or $N.m^{-2}$ (Newton per square metre)

ε = Strain

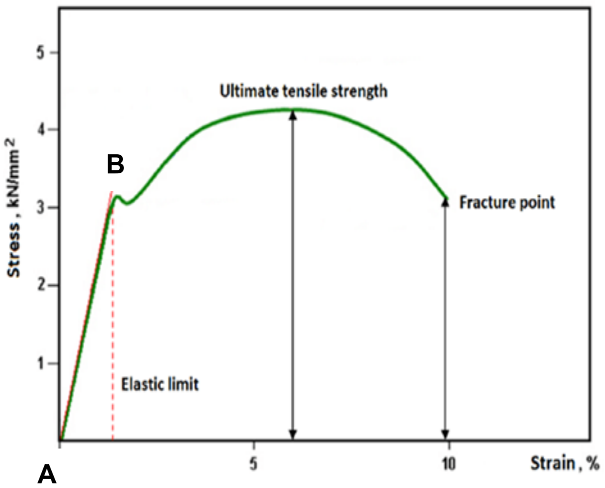
K = Young's Modulus of Elasticity in Pa (Pascal)

4.9.1 Graphical Representation of Stress and Strain relationship



The graph above indicates that, when the **stress** (σ) increases on a material the **strain** (ε) also increases.(Hooke's Law).

4.9.2 Regions of the **Stress** (σ) vs **Strain** (ε)Graph



Taken from:your electricalguide.com

INTERPRETATION OF (σ)vs (ε) GRAPH:

Region A-B:

- is elasticity region the material will regain its original shape and size when the deforming force is removed.

Point B:

- is the elastic limit, an increase in Stress the material may no longer regain its original shape and size

NB:
- Different materials have different Elastic Limits i.e. some materials can withstand more force before breaking than the other materials
- When elastic limit is reached:
  - ➢ Stress (σ) is no longer directly proportional to the strain (ε)
  - ➢ The body is not perfectly elastic anymore; it enters the plastic region and behaves like a plastic body

THINGS TO REMEMBER WHEN DOING ELASTICITY CALCULATIONS

1. The area on which the force is exerted must be in m^2 (square meters).

2. If you have to calculate the area, first convert the lengths given to meters, before calculating the area.

   Examples
   - $1 \text{ mm} = 0{,}001 \text{ m}$ ($1 \div 1000 = 0{,}001 \text{ m}$)
   - $1 \text{ cm} = 0{,}01 \text{ m}$ ($1 \div 100 = 0{,}01 \text{ m}$)

3. If the area is given

   Examples
   - $1 \text{ mm}^2 = 1 \text{ x } 10^{-6} \text{ m}^2$ ($1 \div 1\,000\,000 = 0{,}000\,001\, m_2$
   - $1 \text{ cm}^2 = 1 \text{ x } 10^{-4} \text{ m}^2$ ($1 \div 1\,0000 = 0{,}0001 \text{ m}^2$)

4. The force exerted must be in Newton (N)

   Examples:
   - $1 \text{ kN} = 1 \text{ x } 10^3 \text{ N}$ ($1 \text{ x } 1000 = 1\,000 \text{ N}$)
   - $1 \text{ MN} = 1 \text{ x } 10^6 \text{ N}$ ($1 \text{ x } 1\,000\,000 = 1\,000\,000 \text{ N}$)

5. The stress must be in Pascal (Pa)

   Examples
   - $1 \text{ kPa} = 1 \text{ x}10^3 \text{ Pa}$ ($1 \text{ x } 1000 = 1000 \text{ Pa}$)
   - $1 \text{ MPa} = 1 \text{ x}10^6 \text{ Pa}$ ($1\text{x } 1\,000\,000 = 1\,000\,000 \text{ Pa}$)
   - $1 \text{ GPa} = 1 \text{ x}10^9 \text{Pa}$ ($1 \text{ x } 1\,000\,000\,000 = 1\,000\,000\,000 \text{ Pa}$)

Worked out examples

N4 Engineering Science, pg 143

1. Calculate the maximum force that must be applied by the roof on a pillar with a cross-sectional profile of 400 mm x 450 mm if the compressive stress of 5 Mpa must not be exceeded. (4)

Diagram 1: Pillars supporting the roof

Solution 1:

Given data: ℓ = 400 mm

b = 450 mm $\sigma = 5\ MPa$

Area= ℓ x b

A = 0.4 x 0,45

= 0,18 m²

$$\sigma = \frac{F}{A} \checkmark$$

$$5x10^6 = \frac{F}{0{,}18} \checkmark\checkmark$$

$F =$ **900 000 N** ✓

(NB: Convert the given units to SI units using the table above.)

2. **N4 Engineering Science, pg 153**

A tensile force of 30 kN is applied to a rectangular bar 25 mm x 18 mm. The length of the bar is 2 m and Young modulus for the steel is 200 GPa. Calculate

2.1 The stress (3)

2.2 The final length due to tensile force (7)

Solution 2

2.1 **Given data:**

$\sigma = 30\ kN$,

L = 2 m,

K= 200 GPa

ℓ= 25 mm,

b = 18 mm

Convert the given units to SI units using the table

$$\sigma = \frac{F}{A} \checkmark$$

$$= \frac{30x10^3}{(0{,}025)(0{,}018)} \checkmark$$

= **6.67x10⁷** **Pa**✓

2.2 $K = \dfrac{\sigma}{\varepsilon} \checkmark$

$200x10^9 \checkmark = \dfrac{6{,}67x10^7}{\varepsilon} \checkmark$

ε = **3,34x10⁻⁴**

But $\varepsilon = \dfrac{\Delta l}{L} \checkmark$

$3{,}34x10^{-4} = \dfrac{\Delta l}{2} \checkmark$

$\Delta l = 6{,}68x10^{-4}$

∴ final length = original length+ extension

= 2 + 6,68x10⁻⁴ ✓

= **2.00 m**✓

WORKED EXAMPLE 3

3.1 One end of a wire, 2 m in length, is attached to the ceiling. It has a cross sectional area in the form of a circle with a diameter of 3 mm. An 80kg mass piece is attached to the other end of the wire. Due to this, the length of the wire is increased by 4,4 mm. The mass piece does not touch the floor.

3.1.1 Define the term *stress* in words (2)

Calculate the:

3.1.2 Stress on the wire (7)

3.1.3 Strain of the wire (3)

3.1.4 Wire's elasticity modulus (3)

SOLUTIONS

3.1.1 ***Stress*** is the internal restoring force per unit area of a body. ✓✓ (2)

3.1.2

Radius = $\frac{diameter}{2}$ ✓

= $\frac{0.003}{2}$ ✓

= 1.5×10^{-3} m

Area = πr^2 ✓

= $\pi (1,5 \times 10^{-3})^2$ ✓

= $7,07 \times 10^{-6}$ m^2

$\sigma = \frac{F}{A}$✓

= $\frac{(80)(9.8)}{7.07 \times 10^{-6}}$✓ = 110910.89 Pa or 1.11×10^8✓ (7)

3.1.3 $\varepsilon = \frac{\Delta l}{L}$✓

$= \frac{4,4 \times 10^{-3}}{2}$ ✓

= $2,2 \times 10^{-3}$✓ (3)

3.1.4 $K = \frac{\sigma}{\varepsilon}$✓

$= \frac{1,11 \times 10^8}{2,2 X 10^{-3}}$ ✓

= $5,04 \times 10^{10}$ N · m^{-2} ✓ (3)

ACTIVITIES: ELASTICITY

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (1.1–1.10.) in the ANSWER BOOK, for example 1.11 E.

1.1 The property of a body to regain its original shape and size when the deforming force is removed is known as ...**(2018 EC Sept)**

A plasticity
B elasticity
C strain
D stress (2)

1.2 A mass piece attached to a spring in **Figure 1** below is pulled downward. When released he spring returns to its position of rest as shown in **Figure 2.**

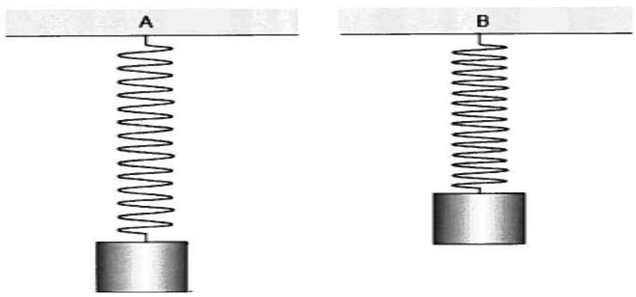


Figure 1 **Figure 2**

The reason for the spring returning to its original position of rest is because…

A its restoring force is inversely proportional to its deforming force
B its restoring force is greater than its deforming force
C its restoring force is less than its deforming force
D its restoring force is equal and opposite to its deforming force (2)

1.3 A force which changes the shape and size of a body is called

A Deforming force
B Frictional force
C Restoring force
D Normal force (2)

1.4 The internal restoring force per unit area of a body is called

A Bulk modulus
B Stress
C Strain
D Young's modulus (2)

1.5 A perfectly elastic body is defined as…

A a body which regains its original shape and size completely when the deforming force is removed.
B a body which does not show a tendency to regain its original shape and size when the deforming force is removed.
C a force per unit area.
D a force which changes the shape and size of a body (2)

1.6 Steel balls of equal masses are dropped into test tubes with motor oils of different viscosities. Which **ONE** of the following has the lowest viscosity?

A B C D (2)

1.7 Hooke's law gives a relationship between stress and strain. Which ONE of the following is the CORRECT relationship between stress and strain, according to Hooke's law

A Strain is directly proportional to the stress that causes it, even if the limit of elasticity is exceeded.
B Strain is inversely proportional to the stress that causes it, if elasticity is not exceeded.
C Stress is inversely proportional to strain within the limit of elasticity.
D Stress is directly proportional to strain within the limit of elasticity. (2)

1.8 Which term best describes a force that is equal and opposite to the deforming force?

A Restoring force
B Applied force
C Stress
D Strain (2)

1.9 Which ONE of the following statements is CORRECT about a liquid with a low viscosity? It..

A is a thicker fluid.
B flows slowly.
C flows quickly.
D has a high fluid friction. (2)

1.10 An oil with designation of **SAE 20W-50** is recommended for

A SUMMER
B AUTUMN
C WINTER
D SPRING (2)

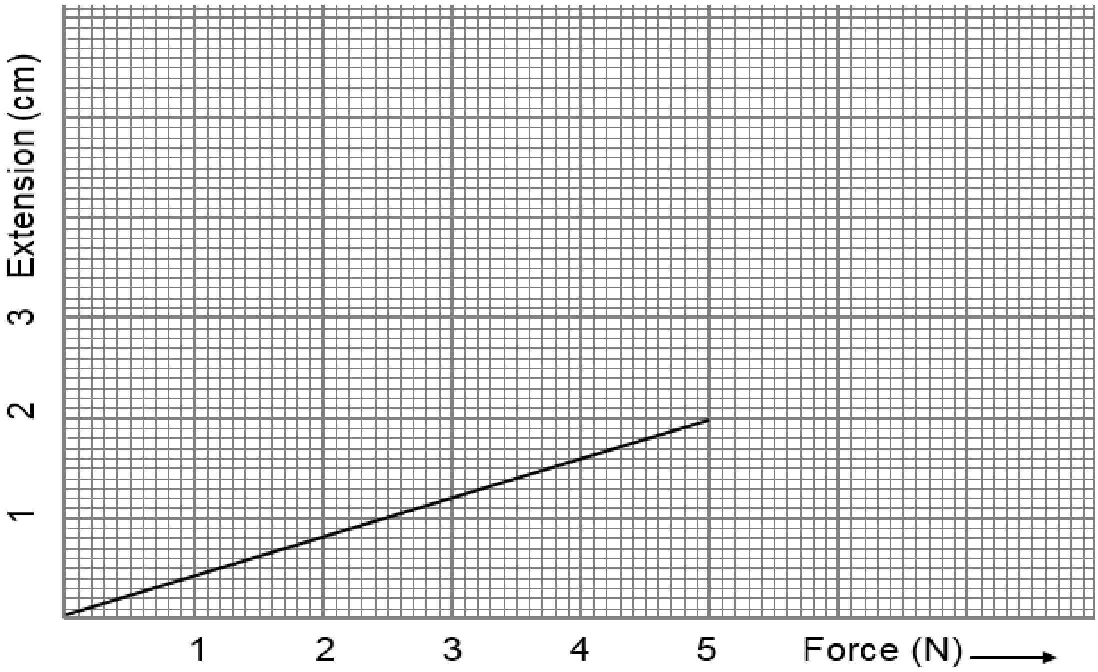
1.11 The viscosity of motor oil INCREASES when the ... the oil DECREASES.

A temperature of
B pressure on
C density of
D mass of (2)

STRUCTURED QUESTIONS
QUESTION 2 (QUESTION 6 EC SEPT 2018)

2.1 Grade 12 students carry out an experiment to find out how far a spring stretches when loads are added to it. The results obtained are used to draw the following graph. The unloaded length of the spring is 15 cm.

FORCE vs EXTENSION



2.1.1 What is the extension of the spring when the applied force is 3 N? (1)

2.1.2 When an object of unknown mass 'm' is hung on the spring, the length of the spring is 1,7 cm. Calculate the mass 'm'. (4)

2.1.3 Define the term strain (2)

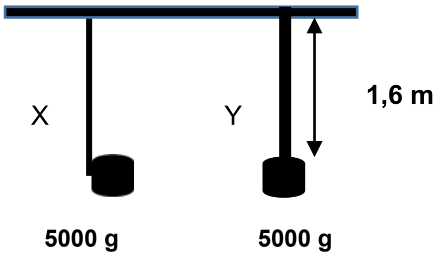
2.1.4 Calculate strain for a force of 5 N by using the information given in graph. (4)

2.2 A steel wire has a strain of $3,6 \times 10^{-4}$ and the modulus of elasticity is 2×10^{11} Pa.

2.2.1 State Hooke's law. (2)

2.2.2 Calculate the stress. (3)

2.3 Two elastic cylindrical rods (A and B) made from the same TYPE of metal have a length of 1,6 m and are attached to the beam. Two 5000 g mass pieces are attached to each rod. The diameter of rod B is double the diameter of rod A. **(GP TSCE Sept 2019)**



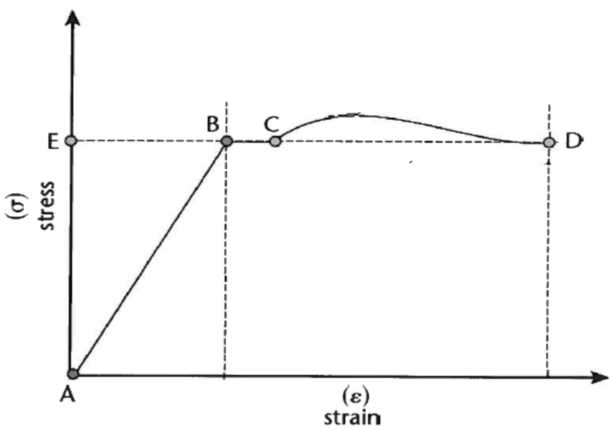
Define:

2.3.1 Strain (2)
2.3.2 Stress (2)

2.4 Use the diagram above to answer questions that follow

2.4.1 If the stress on the rod A is 1,6 x10^9 Pa, calculate the cross section area of rod A (6)
2.4.2 Calculate the stress on the rod B (2)
2.4.3 The equilibrium length of rod B was 15 cm. If rod B is extended by 20%, use relevant formula to calculate the strain of rod B. (4)
2.4.4 Calculate Young's modulus of elasticity for rod B (4)

2.5 **The graph below represents the ratio of Stress versus Strain.**



2.5.1 What does point **B** represent on the graph? (1)
2.5.2 In which region will an object return to its original shape and size when the deforming force is removed? (CHOOSE between, A and B,B and C or C and D) (1)
2.5.3 State Hooke's law in words. (2)
2.5.4 Between which TWO points, indicated on the graph, represent the region where Hooke's law is obeyed? (1)

2.6 A force of 4 kN is applied to a square rod with sides of 200 mm and a length of 3 m as shown below. The change in length after the application of the deforming force is 0,6 mm
Calculate the following:

2.6.1 The stress (3)
2.6.2 The strain (3)
2.6.3 Young's modulus (3)

QUESTION 3

3.1 Define **Viscosity** (2)
3.2 Use the information in the motor oil container given below to answer the questions that follow:

What is the meaning of:
3.2.1 **SAE** (1)
3.2.2 **15** (1)
3.2.3 **W** (1)
3.2.4 **40** (1)

3.3 Differentiate between a **Monograde oil** and a **Multigrade oil** (2)

DATA FOR TECHNICAL SCIENCES GRADE 12
PAPER 1

TABLE 1: PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Acceleration due to gravity	g	$9,8\ m \cdot s^{-2}$
Speed of light in a vacuum	c	$3,0 \times 10^{8}\ m \cdot s^{-1}$
Planck's constant	h	$6,63 \times 10^{-34}\ J \cdot s$
Coulomb's constant	k	$9,0 \times 10^{9}\ N \cdot m^{2} \cdot C^{-2}$
Charge on electron	-e	$-1,6 \times 10^{-19}\ C$
Electron mass	m_e	$9,11 \times 10^{-31}\ kg$

TABLE 2: FORMULAE
FORCE

$F_{net} = ma$	$p = mv$
$f_s^{max} = \mu_s N$	$f_k = \mu_k N$
$F_{net} \Delta t = \Delta p$ $\Delta p = mv_f - mv_i$	$F_g = mg$
Torque = F x r	MA = $\frac{L}{E} = \frac{e}{I}$

WORK, ENERGY AND POWER

$W = F\Delta x \cos\theta$	$U = mgh$ or $E_P = mgh$
$K = \frac{1}{2}mv^2$ or $E_k = \frac{1}{2}mv^2$	$W_{net} = \Delta K$ or $W_{net} = \Delta E_k$ $\Delta K = K_f - K_i$ or $\Delta E_k = E_{kf} - E_{ki}$
$W_{nc} = \Delta K + \Delta U$ or $W_{nc} = \Delta E_k + \Delta E_p$	$P = \frac{W}{\Delta t}$
$P_{ave} = Fv_{ave}$	$M_E = E_k + E_p$

ELASTICITY, VISCOSITY AND HYDRAULICS

$\sigma = \frac{F}{A}$	$\varepsilon = \frac{\Delta \ell}{L}$
$\frac{\sigma}{\varepsilon} = K$	$\frac{F_1}{A_1} = \frac{F_2}{A_2}$

ELECTROSTATICS

$F = \frac{kQ_1Q_2}{r^2}$	$E = \frac{kQ}{r^2}$
$Q = \frac{Q_1 + Q_2}{2}$	$E = \frac{F}{q}$
$n = \frac{Q}{e}$ or $n = \frac{Q}{q_e}$	$E = \frac{V}{d}$
$C = \frac{Q}{V}$	$C = \frac{\varepsilon_o A}{d}$

CURRENT ELECTRICITY

$R=\frac{V}{I}$	emf(ε)= $I(R + r)$
$R_s = R_1 + R_2 + ...$ $\frac{1}{R_p}=\frac{1}{R_1}+\frac{1}{R_2}+ ...$	$q = I\ \Delta t$
$W = VQ$ $W = VI\Delta t$ $W = I^2R\Delta t$ $W = \frac{V^2\Delta t}{R}$	$P=\frac{W}{\Delta t}$ $P = VI$ $P = I^2R$ $P = \frac{V^2}{R}$

ELECTROMAGNETISM

$\phi = BA$	$\varepsilon = -N\frac{\Delta\phi}{\Delta t}$
$\frac{V_s}{V_p}=\frac{N_s}{N_p}$	

SOLUTIONS TO ELASTICITY & VISCOCITY ACTIVITIES

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

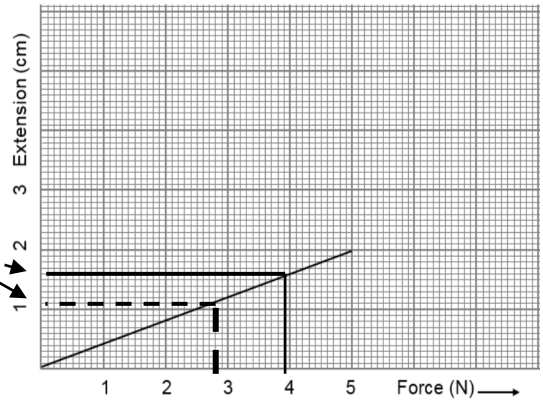
1.1 B ✓✓ 1.2 D ✓✓ 1.3 A ✓✓ 1.4 B ✓✓ 1.5 A ✓✓ 1.6 A ✓✓

1.7 D ✓✓ 1.8 A✓✓ 1.9 C ✓✓ 1.10 A ✓✓ 1.11 A ✓✓

2 x 11 = 22

QUESTION 2

FOR ENRICHMENT : 2.1.1 & 2.1.2 obtained from the graph given



2.1.1 1,2 cm ✓ (1)

2.1.2 At 1,7 cm, Force applied = 4,2 N ✓

Force = weight

Then: $w = mg$ ✓

$4,2 = m \times 9,8$ ✓

$m = 0,43\,kg$ ✓ (4)

2.1.3 **Strain** is the ratio of change in dimension to the original dimension. ✓✓ (2)

2.1.4 **Given data**:

Original length(L) = 15 cm **(0,15 m)**

Change in length (ΔL) = 2 cm **(0,02 m)**

(**NB**: convert **cm** to **m**)

$\varepsilon = \frac{\Delta \ell}{L}$ ✓

$= \frac{0,02}{0,15}$ ✓ ✓

$= 0,13$ ✓ (4)

2.2.1 Hooke's law states that within the limit of elasticity, stress is directly proportional to the strain. ✓✓ (2)

2.2.2 **Given data:** K= 2 x 10^{11} Pa ε = 3,6 x10^{-4} $\sigma = ?$

$K = \frac{\sigma}{\varepsilon}$ ✓

$2 \times 10^{11} = \frac{\sigma}{3,6 \times 10^{-4}}$ ✓

$\sigma = 7,2 \times 10^{7}$ Pa ✓ (3)

2.3.1 Stress is the internal restoring force per unit time. ✓✓ (2)

2.3.2 Strain is the ratio of change in length to the original length. ✓✓ (2)

2.4.1 **Given data:**

For **Rod A**: m_A = 5000 g **(5 kg)**	σ= 1,6 x10^9 Pa	L = 15 cm **(0,15 m)**	$\varepsilon = ?$
For **Rod B**: m_B = 5000 g **(5 kg)**	$\sigma = ?$	d_B= 2 x d_A	

Stress on Rod B:

$$\sigma = \frac{F}{A} \quad ✓$$

$$1,6 \times 10^9 = \frac{49}{A} \quad ✓$$

$A = 3,06 \times 10^{-8}$ m^2 ✓

Remember that in this case: F= w

w=mg

=5 x 9,8

= 49 N

(3)

2.4.2 **Stress on Rod B:**

$$\sigma = \frac{F}{A}$$

$$= \frac{49}{2(3,06 \times 10^{-8}} \quad ✓$$

$=8,01 \times 10^{-8}$ Pa ✓

(2)

2.4.3 20% of 15 cm = 3 cm ✓

$$20\% = \frac{20}{100}$$

$$\frac{20}{100} \times 15 = 3$$

$$\varepsilon = \frac{\Delta l}{L} \quad ✓$$

$$= \frac{3}{15} \quad ✓$$

= 0,2 ✓ (**NB**: strain has no units)

(4)

2.4.4

$$K = \frac{\sigma}{\varepsilon} \quad ✓$$

$$= \frac{8,01 \times 10^8}{0,2}$$

$= 4,0 \times 10^9$ Pa ✓

(2)

2.5.1 Elasticity limit

2.5.2 A and B

2.5.3 Hooke's law states that , within the limit of elasticity stress is directly proportional to strain.

2.6.1 $\sigma = \frac{F}{A}$ ✓

$= \frac{4\ 000}{0,6}$ ✓

$= 6,67 \times 10^3$ Pa ✓

Conversion:

- F= 4 kN

  = 4000 N

- A = L x b

  = 3 x 0,2

  = 0,6 m²

(3)

2.6.2 $\varepsilon = \frac{\Delta l}{L}$ ✓

$= \frac{0,6 \times 10^{-3}}{3}$ ✓

$= 2,0 \times 10^{-3}$ ✓

(3)

2.6.3 $K = \frac{\sigma}{\varepsilon}$ ✓

$= \frac{6,67 \times 10^3}{2,0 \times 10^{-3}}$ ✓

$= 3,33 \times 10^{-6}$ Pa ✓

(3)

QUESTION 3

3.1	Viscosity is the property of the fluid to oppose relative motion between the two adjacent layers. ✓✓	(2)
3.2.1	**SAE** means **S**ociety of **A**utomotive **E**ngineers. ✓	(1)
3.2.2	**15** indicates the viscosity as rated at 0^0C ✓	(1)
3.2.3	**W** stands for **Winter** ✓	(1)
3.2.4	**40** stands for the viscosity at 100 ^{0}C ✓	(1)

3.3

Monograde oil	Multigrade oil
• Is only suitable for use within a very narrow temperatures ✓✓	• Is the oil that can fulfil two viscosity specifications. ✓✓

(4)

5. ACKNOWLEDGEMENT

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