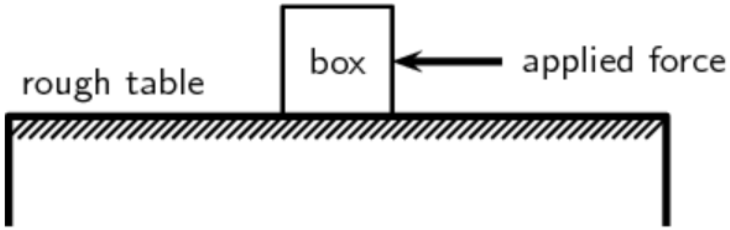
SUBJECT and GRADE	Physical Sciences; Grade 11
TERM 1	Week 5
TOPIC	Newton's second and third laws of motion. *(Focus areas: Second and Third law)*
AIM OF LESSON	**At the end of this lesson you should be familiar with the following:** • Stating Newton's second law in words and supplying the formula *($F_{net} = ma$)* associated with it. • Drawing force diagrams for objects that are in equilibrium *(at rest or moving with constant velocity)* and accelerating *(non-equilibrium)*. • Applying Newton's laws to a variety of equilibrium and non-equilibrium problems including a single object moving on a horizontal/ inclined plane *(frictionless and rough)*, vertical motion and also two-body systems such as two masses joined by a light *(negligible mass)* string. • Understand apparent weight. • Stating Newton's third law in words and understanding *(applying / explaining)* the concept in different scenarios. • Identify action-reaction pairs and listing the properties of these pairs.
RESOURCES	**Paper-based / physical resources** • Prescribed CAPS Physical Sciences textbook, as well as Siyavula Grade 11 Physical Sciences resource (learner book, pg. 77 - 123); Physical Sciences CAPS document (pg. 64 - 65); and Grade 11 Physical Sciences Examination Guideline (pg. 8 - 9). *(Additional subject-related material, e.g. Mind the Gap, Science Clinic, Answer Series, etc.)*. • Scientific calculator, ruler, pen and pencil.

	Digital resources • Technological devices such as a cell phone, tablet, laptop, etc. and sufficient data would be very useful. WCED ePortal – Website links to access recommended platforms: *http://wcedeportal.co.za/; https://wcedonline.westerncape.gov.za/elearning; https://wcedeportal.co.za/curriculum-support; https://wcedeportal.co.za/partners* • Siyavula links (Forces): *https://intl.siyavula.com/read/science/grade-11/newtons-laws/02-newtons-laws-02* • Youtube videos: *https://www.youtube.com/watch?v=kKKM8Y-u7ds; https://www.youtube.com/watch?v=zxvBSQx3SYg* • Mind the Gap: *https://www.education.gov.za/Curriculum/LearningandTeachingSupportMaterials(LTSM)/MindtheGapStudyGuides.aspx*
INTRODUCTION	Use the following link to enhance your knowledge by watching the video which summarizes Newton's laws and bringing it into perspective. https://www.youtube.com/watch?v=kKKM8Y-u7ds
CONCEPTS AND SKILLS	***This section must be read in conjunction with the CAPS, pg. 64 - 65.*** **1. NEWTON'S SECOND LAW OF MOTION** According to Newton's first law which we have covered during previous lessons, an object moving wants to continue to move *(in a straight line and at constant speed),* and if it is stationary, it tends to remain stationary. So what cause objects to start moving? Let us look at the example of a 10 kg box on a rough table. If we push slightly *(e.g. with 100 N force)* on the box as indicated in the diagram below, the box remains in its stationary position. The frictional force is then also 100 N exerted onto the block and avoids movement of the clock. If we increase the force *(for e.g. 150 N)* and the box is on the

verge of moving, the frictional force is 150 N. To be able to move the box, we need to push hard enough to overcome this friction. Thus, when we apply a force of 200 N, the 'first' 150 N will be used to overcome or 'cancel' the friction and the other 50 N will be used to move *(accelerate)* the block. In order to accelerate an object, there must be a resultant force present.



Now, what do you think will happen if we push harder and apply a greater force on the block? Or what will happen if the block was heavier *(greater in mass)*? Do you think these factors will influence the movement *(acceleration)* of the block?

Hopefully your response to the last question was “YES”.

EXPLANATION:
The greater force applied, the faster the block will move, i.e. greater acceleration. The acceleration of the block is therefore directly proportional to the resultant force. In mathematical terms: $a \propto F$

However, if the block was greater in mass while the same magnitude of force is applied, then the movement *(acceleration)* of the block would have been slower. Thus, the acceleration is inversely proportional to the mass. In mathematical terms: $a \propto 1/m$.

The following is obtained when rearranging the above relationships:

$$a \propto F/m \quad \textit{or} \quad F = ma$$

Remember that both force and acceleration are vectors quantities. The acceleration is in the same direction as the force that is being applied. If multiple forces are acting simultaneously then we only need to work with the resultant force or net force.

This brings us to the definition of Newton's second law of motion:

DEFINITION: If a resultant *(net)* force acts on a body, it will cause the body to accelerate in the direction of the resultant force. The acceleration of the body will be directly proportional to the resultant force and inversely proportional to the mass of the body. *(The mathematical representation is: $F_{net} = ma$)*

Applying Newton's second law of motion

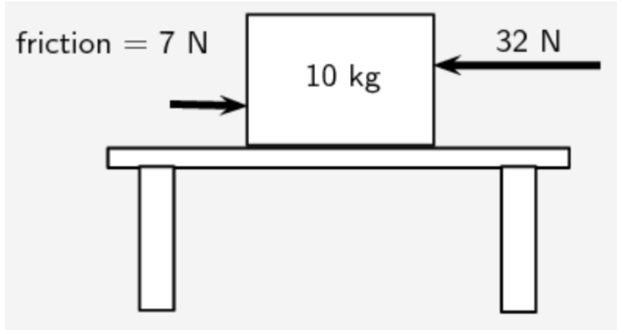
Newton's second law can be applied to a variety of situations. The following is a typical example where the law can be used.

Worked out example: Newton's second law

QUESTION:

A 10 kg box is placed on a table. A horizontal force of magnitude 32 N is applied to the box. A frictional force of magnitude 7 N is present between the surface and the box.

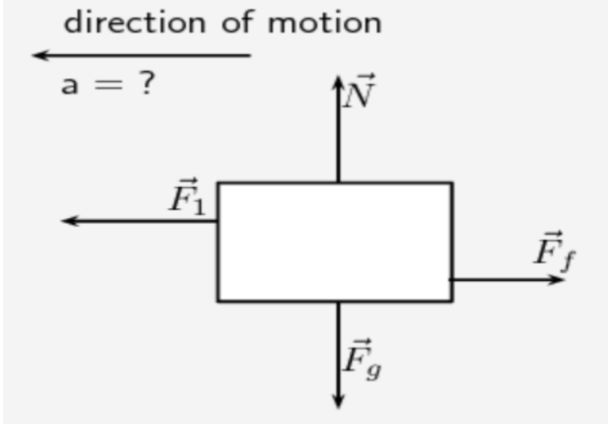
1. Draw a force diagram indicating all of the forces acting on the box.
2. Calculate the acceleration of the box.



SOLUTION:

Step 1: Identify the horizontal forces and draw a force diagram.

We only look at the forces acting in a horizontal direction *(left-right)* and not vertical *(up-down)* forces. The applied force and the force of friction will be included. *(The force of gravity, which is a vertical force, will not be included)*.



Step 2: Calculate the <u>acceleration</u> of the box.

Remember that we consider the y- and x-directions separately. In this problem we can ignore the y-direction because the box is resting on a table with the gravitational force balanced by the normal force.

We have been given:

- Applied force F_1 = 32 N
- Frictional force F_f = −7 N
- Mass m = 10 kg

To calculate the acceleration of the box we will be using the equation $F_R = ma$.

Therefore: $F_R = ma$

$F_1 + F_f = (10)a$

$(32 - 7) = (10)a$

$25 = (10)a$

$a = 0{,}25\ m.s^{-2}$ *na links*

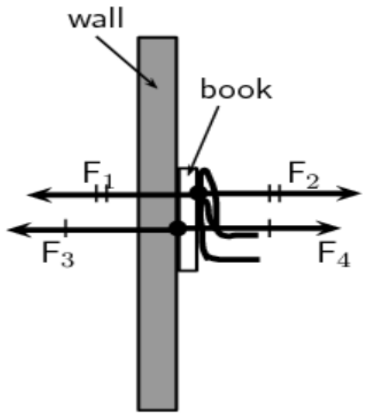
2. NEWTON'S THIRD LAW OF MOTION

Newton's third law of motion explains to us the interaction between pairs of objects. Example: When pressing a book against a wall, you are exerting a force on the book, while the book exerts a force back at you. Take note of the fact that, if the book was not pushing back, your hand would go through the book. These two forces working together *(i.e. F_1: force of hand on book; and F_2: force of book on hand)* are referred to as action-reaction pairs of forces. They are equal in magnitude but exerted in opposite directions. These forces also act on different objects, such as in this case where the one force acts onto the book and the other onto your hand.

Figure: Action-reaction force pairs

Apart from the previously mentioned, there is also another action-reaction force pair present in this situation, which include the book pushing against the wall *(F_3: action force)* and the wall pushing back onto the book *(F_4: reaction force)*. Refer to the following diagram illustrating the two force pairs.

F1: force of hand on book
F2: force of book on hand
F3: force of book on wall
F4: force wall on book



This brings us to the definition of Newton's third law of motion:

DEFINITION: If body A exerts a force on body B, then body B exerts a force on body A, which is equal in magnitude but opposite in direction.

Please familiarize yourself with the properties concerned with action-reaction force pairs, which include:

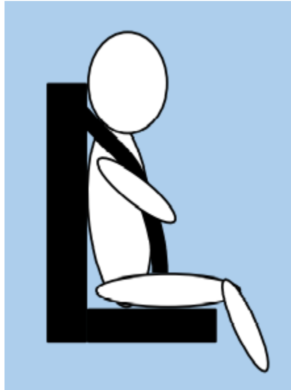
- the same type of force acts on both objects;
- the forces have the same magnitude but opposite direction; and
- the forces act on different objects.

Newton's action-reaction pairs can be observed all around us where two objects interact with one another. Refer to the following example where Newton's third law is applied:

Worked out example: Newton's third law

QUESTION:

Sipho is seated in the passenger seat of a car with the seat belt on. The car suddenly stops and he moves forward *(Newton's first law - he continues in his state of motion)* until the seat belt stops him. Draw a labelled force diagram identifying two action-reaction pairs in this situation.



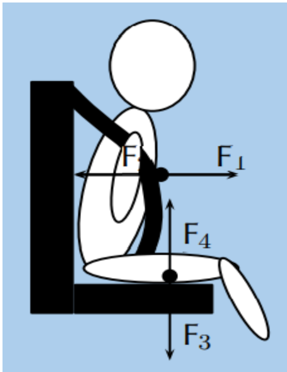
SOLUTION:

Step 1: <u>Draw</u> a force diagram.

Start by drawing the picture. You will be <u>using arrows to indicate the forces</u> so make your picture large enough so that detailed labels can also be added. *(No need for artistic work, just as long as your picture represents the forces accurately).*

Step 2: <u>Label</u> the diagram.

Take one pair at a time and label them carefully. If there is not enough space on the drawing, then use a key on the side.



F1: Force of Sipho on safety belt.
F2: Force of safety belt on Sipho.
F3: Force of Sipho on seat (downwards).
F4: Force of seat on Sipho (upwards).

<u>Table</u>: Please ensure that you familiarise yourself with the following physical quantities, units and symbols, which will be needed for the sections of the work that will follow.

Physical quantity	Unit name	Unit symbol
Distance (d)	meter	m
Weight (N)	Newton	N
Force (F)	Newton	N
Mass (m)	Kilogram	kg
Tension (T)	Newton	N
Acceleration (a)	Meter per second squared	$m.s^{-2}$

Extracted and summarized from: Siyavula Grade 11 Physical Sciences resource (learner book, pg. 77 - 123); Physical Sciences CAPS document (pg. 64 - 65); and Grade 11 Physical Sciences Examination Guideline (pg. 8 - 9).

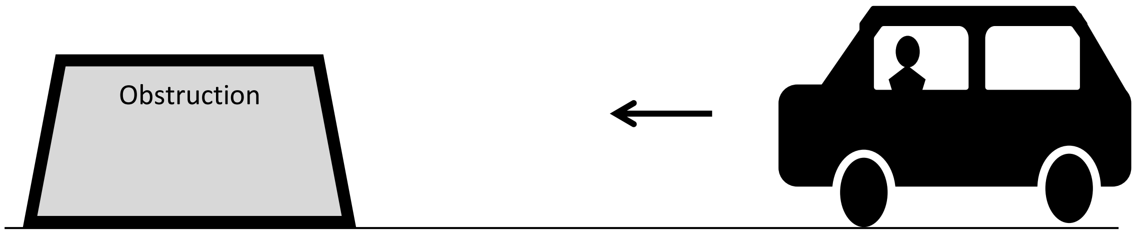
EXERCISES FOR CONSOLIDATION PURPOSES

Please use ample time to complete the following activities (questions 1 to 3), which will aid in preparing you for tests / examinations in future.

QUESTION 1

Various options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1 – 1.3), for example 1.1.11 E.

1.1 A car is travelling along a road. The driver has his seat belt on. The driver sees an obstruction in the road ahead and suddenly applies the brakes.



An action-reaction pair is the force of the seat belt on the driver and the force of the …

A driver on the seat.
B wheels on the road.
C driver on the seat belt.
D seat belt on the seat.

1.2 A net force, **F**, is applied on an object of mass ***m*** kg and causes an acceleration of ***a*** $m \cdot s^{-2}$. When the net force, **F**, on the same object is doubled, the resulting acceleration, in $m \cdot s^{-2}$, will be ...

A 4F
B a
C 2*a*
D 3*a*

1.3 A person stands on a bathroom scale in a stationary elevator. The reading on the scale is 490 N. When the elevator is in motion, the reading on the scale changes to 470 N.

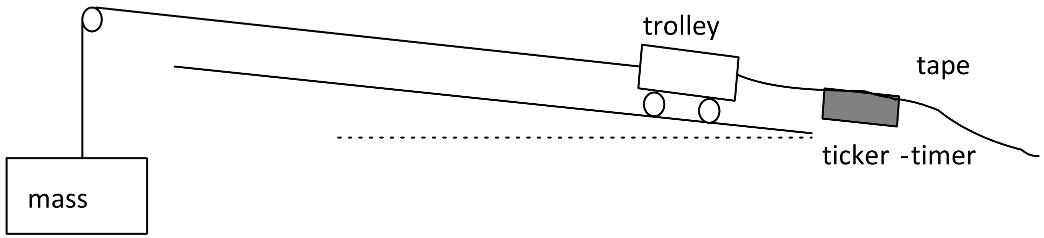
Which ONE of the following combinations best describes the DIRECTION OF THE MOTION and the DIRECTION OF THE ACCELERATION of the elevator during the motion?

	DIRECTION OF THE MOTION	**DIRECTION OF THE ACCELERATION**
A	Upwards	Upwards
B	Downwards	Downwards
C	Upwards	Downwards and then upwards
D	Downwards	Upwards and then downwards

[3 x 2 = 6]

QUESTION 2

Learners investigate the relationship between net force and acceleration by pulling a trolley across a surface which is slightly inclined to compensate for friction. The trolley is connected to different masses by a string of negligible mass. The string passes over a frictionless pulley. Refer to the diagram below.



Ticker-tape attached to the trolley passes through the ticker-timer. The acceleration of the trolley is determined by analyzing the ticker-tape. The results of the net force produced by the different masses and the acceleration of the trolley were recorded in the table below.

NET FORCE (N)	a ($m \cdot s^{-2}$)
0,3	0,36
0,6	0,73
0,9	1,09
1,2	1,45

2.1 Write down a hypothesis for this experiment. (2)

2.2 Identify the:

2.2.1 *independent variable*. (1)

2.2.2 *controlled variable*. (1)

2.3 Draw a graph of the acceleration versus net force. (4)

2.4 Calculate the gradient of the graph. (3)

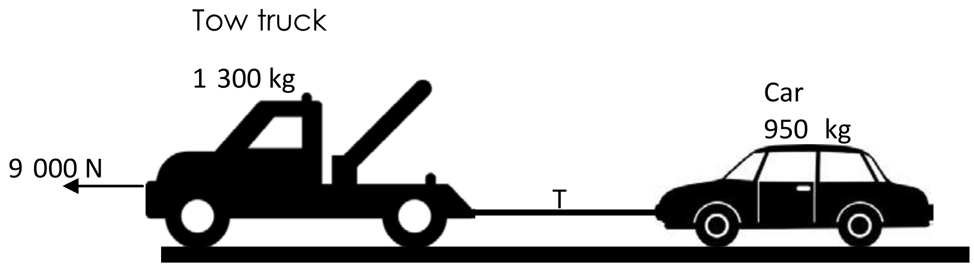
2.5 Use the gradient of the graph calculated in QUESTION 2.4 to determine the mass of the trolley. (2)

[13]

QUESTION 3

A tow truck pulls a car along a gravel road.

The force applied by the engine of the tow truck is 9 000 N. The mass of the tow truck is 1 300 kg and the mass of the car is 950 kg. The vehicles are connected to each other by an inelastic tow bar of negligible mass. See the diagram below.



The tow truck and car move at a CONSTANT VELOCITY.

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

3.2 NAME AND STATE the law that explains why the force exerted by the tow truck on the car is the same as the force exerted by the car on the tow truck. (3)

3.3 Draw a labelled free-body diagram indicating all the forces acting on the tow truck. (5)

3.4 If the coefficient of kinetic friction between the tow-truck tyres and the road surface is 0,45, calculate the: 3.4.1 Magnitude of the tension in the tow bar (5) 3.4.2 Coefficient of kinetic friction between the CAR tyres and the road surface (5) Suddenly the tow bar between the car and the tow truck disconnects and the car comes loose. 3.5 Using a relevant law of motion, explain why the car continues moving forward for a short distance. (3) 3.6 Calculate the acceleration of the car as it comes to a stop after a short distance. (3) **[26]** **TOTAL = 45**	
CONSOLIDATION	**Summary of lesson content, which you should be familiar with at this stage:** • State Newton's second law of motion: When a resultant/net force acts on an object, the object will accelerate in the direction of the force at an acceleration directly proportional to the force and inversely proportional to the object's mass. • Draw force diagrams and free-body diagrams for objects that are in equilibrium or accelerating. • Apply Newton's second law of motion to a variety of equilibrium and non-equilibrium problems, including: a single object; and two-body systems. • NOTE: When an object accelerates, the equation $F_{net} = ma$ must be applied separately in the x and y directions. If there is more than one object, a free-body diagram must be drawn for each object and Newton's second law must be applied to each object separately. • State Newton's third law of motion: When object A exerts a force on object B, object B SIMULTANEOUSLY exerts an oppositely directed force of equal magnitude on object A. • Identify Newton III force pairs *(action-reaction pairs)* and list the properties of the force pairs *(action-reaction pairs)*. When identifying the forces it must be clearly stated which body exerts a force on which body, and what kind of force it is, e.g. the earth exerts a downward gravitational force on the object, and the object exerts an upward gravitational force of equal magnitude on the earth. Link to the memo: https://drive.google.com/file/d/1Og2kJcbRX6XFIfhVV5RTmYBD2-KV52RU/view?usp=sharing

VALUES / APPLICATIONS IN PRACTICE	**Value of Newtons laws of motion in everyday practices.** Visit the following weblink and watch the video illustrating the value of using Newton's laws of motion to explain some of the activities we are engaged with in our daily lives, which include understanding: • Newton's first law and inertia when swinging, ice skating and cycling. • Newton's second law when vehicles suddenly stop and the movement *(acceleration)* of objects with different masses. • Newton's third law and action-reaction force pairs in activities concerned with bouncing balls, jumping, walking, and cycling. **A look into real-life applications of Newton's laws:** *https://www.youtube.com/watch?v=zxvBSQx3SYg*