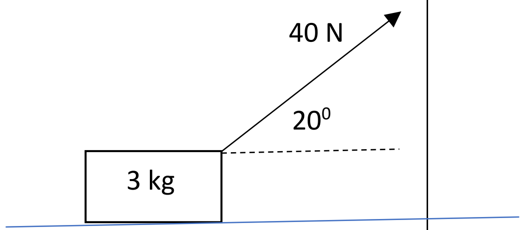
SUBJECT and GRADE	Physical Sciences; Grade 11
TERM 1	Week 6
TOPIC	Newton's second law of motion.
AIM OF LESSON	**At the end of this lesson you should be familiar with the following:** Apply Newton's second law of motion to a variety of equilibrium and non-equilibrium problems including Two-body systems (joined by a light inextensible string): • Both on a flat horizontal plane with or without friction • One in a horizontal plane with or without friction, and a second hanging vertically from a string over a frictionless pulley • Both on an inclined plane with or without friction • Both hanging vertically from a string over a frictionless pulley
RESOURCES	**Paper-based / physical resources** • Prescribed CAPS Physical Sciences textbook, • 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 (pg 19 – 26), 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: https://wcedeportal.co.za/eresource/189921 • 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**

	Recapping from the previous lesson, Newton's Second law of motion is an acceleration relationship. Can you recall that the acceleration of the block is directly proportional to the resultant (net) force. In mathematical terms: $a \propto F$ --------(1) AND the acceleration is inversely proportional to the mass. In mathematical terms: $a \propto 1/m$ -----------(2) The following is obtained when rearranging equation (1) and (2) $a \propto \frac{F}{m}$ or $F_{net} = ma$ *Remember that both force and acceleration are vectors quantities. The acceleration is in the same direction as the net (resultant) force and not necessarily in the same direction as the motion of the object. If multiple forces are acting simultaneously then we only need to work with the resultant force or net force.* ***Recall the definition of Newton's second law of motion (this is examinable and is asked almost every year in the final exam.)*** 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. **Applying Newton's second law of motion** Newton's second law can be applied to a variety of situations. Before working through the following examples, go through Mind the Gap pages 19 – 26.

EXAMPLE 1:



A force of 40 N is applied to a block of mass 3 kg, at an angle of 20^0 to the horizontal, as shown alongside. The coefficient of kinetic friction is 0,2.

1.1 Draw a free body diagram showing all the forces acting on the block. (4)

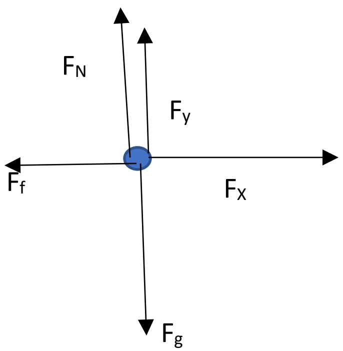
1.2 Calculate the magnitude of the normal force. (4)

1.3 Calculate the kinetic friction force (3)

1.4 Calculate the acceleration of the block. (3)

ANSWER TO EXAMPLE 1

1.1



Drawing the applied force at an angle is not incorrect. But we recommend rather draw the components F_Y and F_X as this will assist you greatly when you get to the calculations.

1.2 In the vertical plane, $F_{net} = 0$, therefore the sum of the forces upwards equal the sum of the forces downwards.

i.e.

$$F_N + F_Y = F_g$$
$$F_N + F_{app}.\sin 20^0 = mg$$
$$F_N = (3)(9{,}8) - 40 \sin 20^0$$
$$= 15{,}719 \text{ N}$$

The normal force is a vertical force. Therefore, from the free-body diagram, focus only on the vertical forces viz. F_N, F_Y and F_G.

1.3

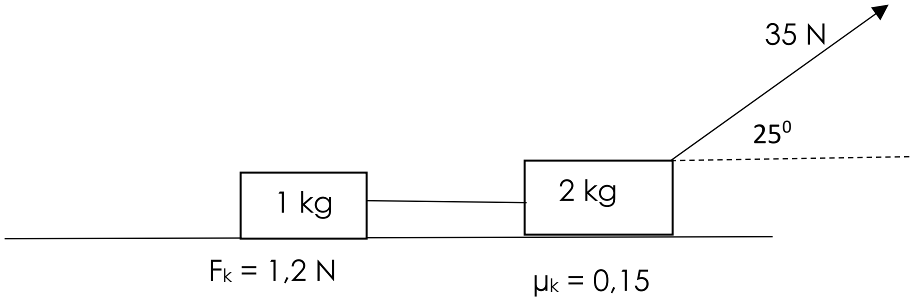
$$F_f = \mu_k N$$
$$= (0,2)(15,719)$$
$$= 3,144 \text{ N}$$

1.4

$$F_{net} = m a$$
$$F_X + F_f = ma$$
$$40.\cos 20^0 - 3,144 = 3a$$
$$a = 34,444 \text{ m}\cdot\text{s}^{-2}\text{, right}$$

The acceleration is now horizontally, therefore focus only on the horizontal forces viz: F_X and F_f.
In the second line, the direction in which the block moves, that force must be written first viz. F_X

EXAMPLE 2:



A block of mass 1 kg is attached to a 2 kg block via a light, inextensible string. A force of magnitude 35 N is applied to the 2 kg block at an angle of 25^0 to the horizontal, as shown above. As the system moves, the 1 kg block experiences a frictional force of 1,2 N and the coefficient of friction on the 2 kg block is 0,15.

2.1 Draw a free body showing all the forces acting on the 2 kg block. (5)

2.2 Calculate frictional force acting on the 2 kg block as it moves. (4)

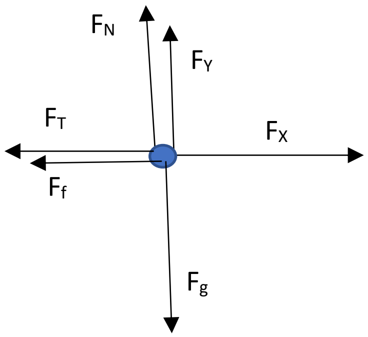
2.3 Calculate the coefficient of kinetic friction experienced by the 1 kg block. (3)

2.4 Calculate the magnitude of the acceleration of the system. (7)

2.5 Hence calculate the tension in the string. (2)

ANSWERS TO EXAMPLE 2

2.1



2.2

$$F_N + F_Y = F_g$$
$$F_N + F_{app}.\sin 25^0 = mg$$
$$F_N = (2)(9,8) - 35 \sin 25^0$$
$$= 4,808 \text{ N}$$

2.3

$F_f = \mu_k N$

$1,2 = \mu_k\,(1)(9,8)$ …….. $N = F_g = mg = (1)(9,8)$

$\mu_k = 0,122$ NB. μ_k does not have any units.

2.4

For the 1 kg block: Draw the horizontal forces acting on the 1 kg block. This will assist in getting the following equation:

$F_{net} = ma$

$F_T + F_k = ma$

$F_T - 1,2 = 1a$

$F_T = 1a + 1,2$ ………….. (1)

For the 2 kg block: From the free-body diagram in q 2.1, look at only the horizontal forces acting on the 2 kg block. This will assist in getting the following equation:

$F_{net} = ma$

$F_X + F_T + F_k = ma$

$35.\cos 25^0 - F_T - 0,721 = 2a$

$F_T = 31 - 2a$ ………….. (2)

$F_f = \mu_k N$
$= (0,15)(4,808)$
$= 0,721$ N

(1) = (2): $1a + 1,2 = 31 – 2a$

$3a = 29,8$

$a = 9,933$ m·s^{-2}

2.5

You can use either eq (1) or eq (2) from q 2.4 to calculate F_T.
I will use eq (1): $F_T = 1a + 1,2$
$= 1(9,933) + 1,2$
$= 11,133$ N

NB. **Step 1**: Whether the question is asked or not you must ALWAYS draw separate free body diagrams for each object indicating ALL the forces acting on the object. Thereafter we only look at the forces acting in the direction of motion (*left-right or up/down 0r along an incline, depending on the question)*.

The applied force (or F_X component) , the tension force and the force of friction will be included only if you working with he horizontal forces.

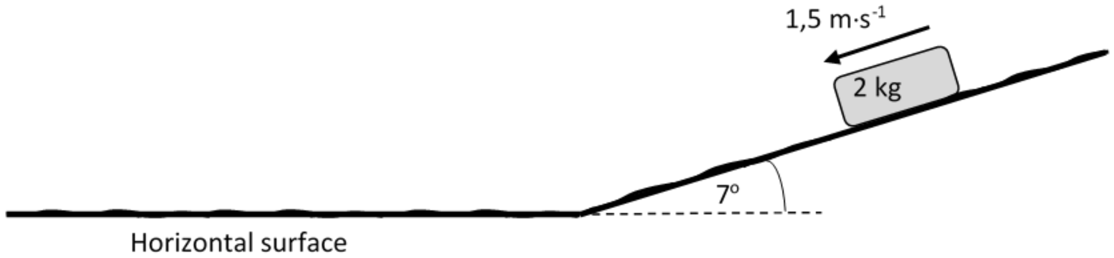
The force of gravity, F_Y component and the normal, will be included only if you working with the vertical forces).

However, the vertical forces must only be considered when you need to calculate friction force, given the coefficient of friction.

Step 2: Calculate the acceleration of the box. Remember that we consider the y- and x-directions separately.

EXAMPLE 3

In the diagram below, a small object of mass 2 kg is sliding *at a constant velocity* of 1,5 $m\cdot s^{-1}$ down a rough plane inclined at 7° to the horizontal surface.



At the bottom of the plane, the object continues sliding onto the rough horizontal surface *and eventually comes to a stop*.

The coefficient of kinetic friction between the object and the surface is *the same for both the inclined surface and the horizontal surface*

3.1 Write down the magnitude of the net force acting on the object. (1)

3.2 Draw a labelled free-body diagram for the object while it is on the inclined plane. (3)

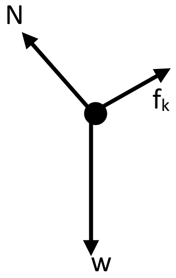
3.3 Calculate the

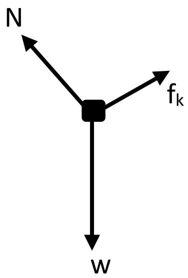
- 3.3.1 Magnitude of the frictional force acting on the object while it is sliding down the inclined plane. (3)
- 3.3.2 Coefficient of kinetic friction between the object and the surfaces. (3)
- 3.3.3 Distance the object travels on the horizontal surface before it comes to a stop. (5)

ANSWER TO EXAMPLE 3

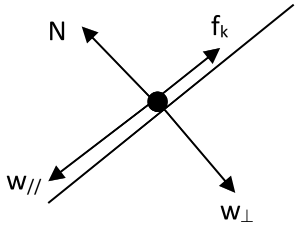
3.1 0 N/zero/*nul*✓ (1)

3.2





ACCEPT/*AANVAAR*



Accepted labels/*Aanvaarde benoemings*		
w	F_g/F_w/weight/mg/gravitational force/N	*F_g/F_w/gewig/mg/gravitasiekrag*
f	$F_{friction}$/F_f/friction/f_k	*$F_{wrywing}$/F_w/wrywing/f_k*
N	F_N/F_{normal}/normal force	F_N/$F_{normaal}$/*normaalkrag*

(3)

3.3.1 $F_{net} = ma$

$f_k - mg\sin\theta = 0$ } ✓ 1 mark for any of these/*1 punt vir enige van hierdie*

$f_k = mg\sin\theta$

$f_k = (2)(9,8)\sin 7°$ ✓

$f_k = 2,39$ N ✓ (2,389) N (3)

3.3.2 $f_k = \mu_k N$

$= \mu_k mg\cos 7°$ } ✓ 1 mark for any of these/*1 punt vir enige van hierdie*

$2,389 = \mu_k(2)(9,8)\cos 7°$ ✓

$\mu_k = 0,12$ ✓ (3)

	3.3.3 $F_{net} = ma$ $- f_k = ma$ $- \mu_k N = ma$ ✓ (1 mark for any of these/*1 punt vir enige van hierdie*) $- \mu_k(mg) = ma$ $- (0,12)(2)(9,8)$ ✓ $= 2a$ ✓ $a = -1,176\ m.s^{-2}$ (-1,18) $v_f^2 = v_i^2 + 2a\Delta x$ $0 = (1,5)^2 + 2(-1,176)\Delta x$ ✓ $\Delta x = 0,96\ m$ Distance is/*Afstand is* 0,96 m

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 According to Newton's Second Law of Motion, the acceleration of an object is

A independent of its mass.

B always equal to its mass.

C directly proportional to its mass.

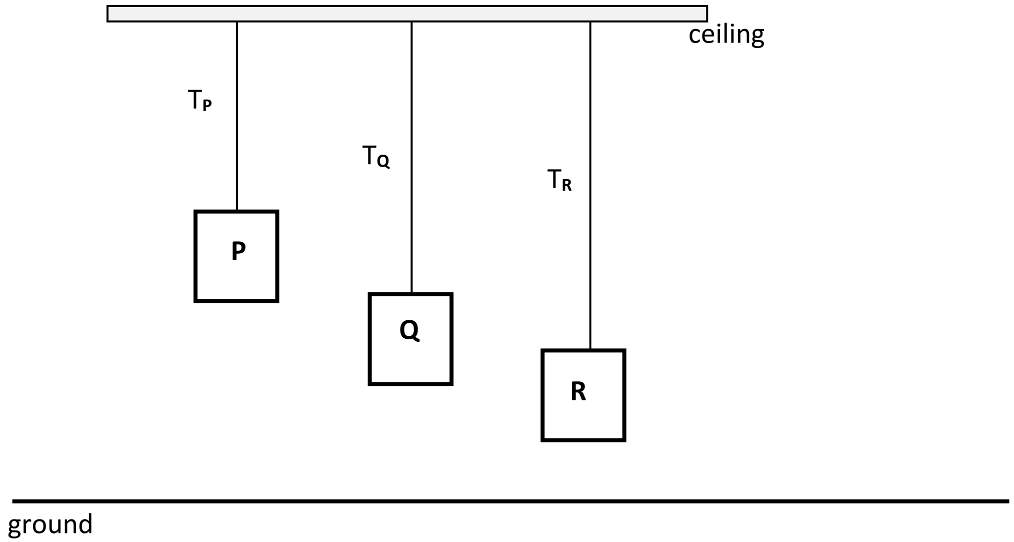
D inversely proportional to its mass. (2)

1.2 A constant horizontal force **F** is applied to a box resting on a horizontal, frictionless surface. Which ONE of the following statements regarding force **F** is CORRECT?

Force **F** will cause the box to move with …

A constant acceleration.
B constant velocity.
C constant kinetic energy.
D constant momentum. (2)

1.3 The diagram below shows three blocks, P, Q and R, suspended from a ceiling. The blocks are *identical*, *stationary* and have the *same mass* but are at different heights above the ground. The connecting strings are massless and inextensible. The tensions in the strings attached to blocks P, Q and R are T_P, T_Q and T_R respectively



Which ONE of the following statements about the tensions is CORRECT?

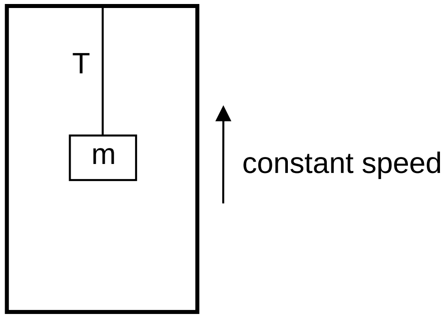
A $T_P > T_Q > T_R$

B $T_P < T_Q < T_R$

C $T_P = T_Q = T_R$

D $T_P > T_Q$ and $T_Q < T_R$ (2)

1.4 An object, of mass m, hangs at the end of a string from the ceiling of a lift cage. The lift is moving upward at CONSTANT SPEED. The acceleration due to gravity is *g*



Which ONE of the following statements regarding the tension (T) in the string is CORRECT? The tension T

A will be equal to m*g*.

B will be less than m*g*.

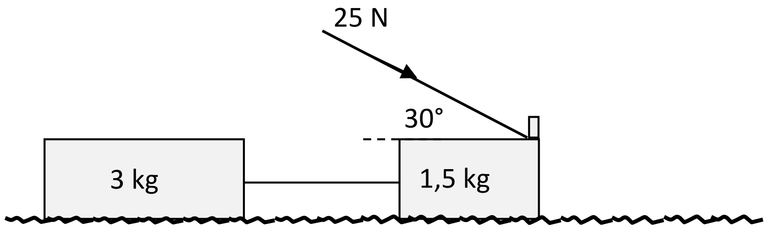
C will be greater than m*g*.

D cannot be determined without knowing the speed of the lift cage. (2)

QUESTION 2

A learner constructs a push toy using two blocks with masses 1,5 kg and 3 kg respectively. The blocks are connected by a massless, inextensible cord

The learner then applies a force of 25 N at an angle of 30° to the 1,5 kg block by means of a light rigid rod, causing the toy to move across a flat, rough, horizontal surface, as shown in the diagram below. The coefficient of kinetic friction (μ_k) between the surface and each block is 0,15



2.1 State Newton's second law of motion in words. (2)

2.2 Calculate the magnitude of the kinetic frictional force acting on the 3 kg block. (3)

2.3 Draw a labelled free-body diagram showing all the forces acting on the 1,5 kg block. (5)

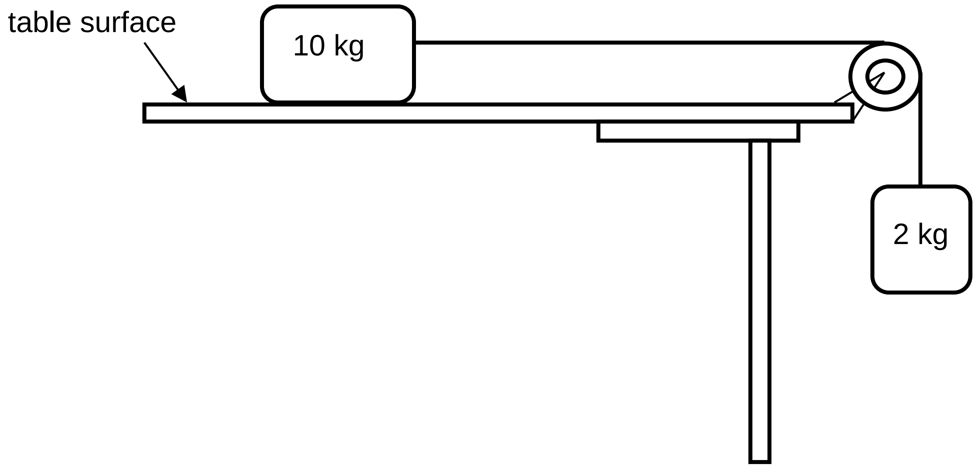
2.4 Calculate the magnitude of the:

2.4.1 Kinetic frictional force acting on the 1,5 kg block (3)

2.4.2 Tension in the cord connecting the two blocks. (5)

QUESTION 3

The diagram below shows a 10 kg block lying on a flat, rough, horizontal surface of a table. The block is connected by a light, inextensible string to a 2 kg block hanging over the side of the table. The string runs over a light, frictionless pulley. The blocks are **stationary**



3.1 State Newton's FIRST law in words. (2)

3.2 Write down the magnitude of the NET force acting on the 10 kg block. (1)

When a 15 N force is applied vertically downwards on the 2 kg block, the 10 kg block accelerates to the right at 1,2 $m \cdot s^{-2}$

3.3 Draw a free-body diagram for the 2 kg block when the 15 N force is applied to it. (3)

3.4 Calculate the coefficient of kinetic friction between the 10 kg block and the surface of the table. (7)

3.5 How does the value, calculated in QUESTION 3.4, compare with the value of the coefficient of STATIC friction for the 10 kg block and the table? Write down only LARGER THAN, SMALLER THAN or EQUAL TO (1)

3.6 If the 10 kg block had a larger surface area in contact with the surface of the table, how would this affect the coefficient of kinetic friction calculated in QUESTION 2.4? Assume that the rest of the system remains unchanged. Write down only INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)

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. Separate equations set up for each object and the two equations solved simultaneously. **ANSWERS TO EXERCISES FOR CONSOLIDATION** **QUESTION 1** 1.1 D 1.2 A 1.3 C 1.4 A

QUESTION 2/*VRAAG 2*

2.1 When a resultant/net force acts on an object, the object will accelerate in the (direction of the net/resultant force). The <u>acceleration is directly proportional to the net force</u> □and <u>inversely proportional to the mass</u> □of the object.

Wanneer 'n netto krag op 'n voorwerp inwerk, versnel die voorwerp in die rigting van die netto krag teen 'n versnelling direk eweredig aan die krag en omgekeerd eweredig aan die massa van die voorwerp. (2)

2.2 $f_k = \mu_k N$✓$= \mu_k mg$

$= \underline{(0,15)(3)(9,8)}$✓

$= 4,41$ N✓

1 mark for any of the formulae

(3)

2.3

Accepted Labels/*Aanvaarde benoemings*	
w	F_g/F_w/force of Earth on block/weight/gravitational force *F_g/F_w/krag van Aarde op blok/gewig/gravitasiekrag*
N	F_N/F_{normal}/normal force $F_N/F_{normaal}$/normalekrag
T	Tension/F_T *Spanning*/F_T
f_k	$f_{kinetic\ friction/kinetiesewrywing}$/$f_{f/w}$/f//$F_{f/w}$kinetic friction/*kinetiesewrywing*
25 N	$F_{applied}/F_A/F$ $F_{toegepas}/F_A/F$

2.4.1

OPTION 1/*OPSIE 1*	OPTION 2/*OPSIE 2*
$f_k = \mu_k N = \mu_k(25\sin 30^\circ + mg)$ $= 0,15[(25\sin30^\circ)✓ + (1,5)(9,8)✓]$ $= 4,08$ N✓	$f_k = \mu_k N = \mu_k(25\cos 60^\circ + mg)$ $= 0,15[(25\cos60^\circ)✓ + (1,5)(9,8)✓]$ $= 4,08$ N✓

(3)

2.4.2

POSITIVE MARKING FROM QUESTION 2.2 AND QUESTION 2.4.1

POSITIEWE NASIEN VANAF VRAAG 2.2 EN VRAAG 2.4.1

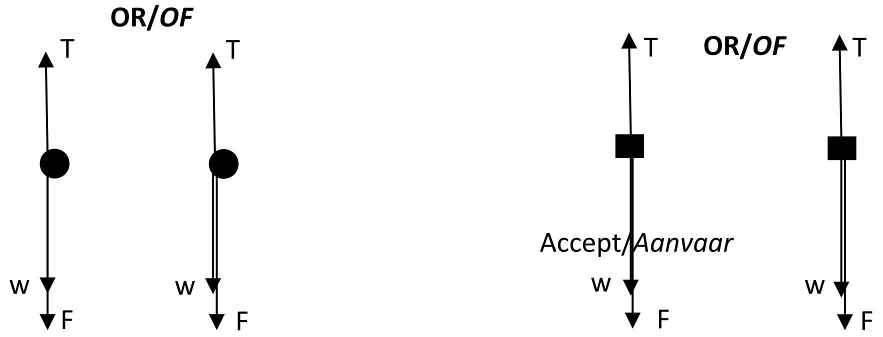
OPTION 1/*OPSIE 1*

For the 1,5 kg block/*Vir die 1,5 kg blok*

$F_{net} = ma$ } ✓

	$F_x + (-T) + (-f_k) = ma$ $25 \cos 30^\circ - T - f_k = 1{,}5a$ $(25 \cos 30^\circ - T) - 4{,}08$ = 1,5a $17{,}571 - T = 1{,}5a$ ....(1) ✓either one For the 3 kg block *Vir die 3 kg blok* $T - f_k = 3a$ $T - 4{,}41$ = 3a ....(2) $13{,}161 = 4{,}5\ a$ $a = 2{,}925\ m \cdot s^{-2}$ T = 13,19 N ✓ (13,17 N – 13,19 N) **QUESTION 3** 3.1 A body will remain in its state of rest or continues at constant velocity in a straight line unless a non-zero resultant/net force acts on it *'n Liggaam sal in sy toestand van rus of beweging teen konstante snelheid 'n 'n reguitlyn bly tensy 'n nie-nul resulterende/netto krag daarop inwerk*

3.2 0 (N)✓/zero/*nul* (newton) (1)



(3)

3.4

$F_{net} = ma$ ✓

$F_a + F_g + (-T) = ma$

$(F_a + mg) + (-T) = ma$

$[15+(2)(9,8) - T]$✓ $= (2)(1,2)$✓

$T = 32,2$ N

$F_{net} = ma$

$T + (-f_{K}) = ma$

$T - \mu_k N = ma$

✓

$T - \mu_k mg = ma$

$32,2 - (\mu_k (10)(9,8))$✓ $= (10)(1,2)$✓

$\mu_k = 0,21$✓ (7)

	3.5 Smaller than/*Kleiner as* ✓ (1) 3.6 Remains the same/*Bly dieselfde* ✓ The coefficient of kinetic friction is independent of the surface areas in contact. *Die kinetiese wrywingskoëffisiënt is onafhanklik van die oppervlakareas waarmee in kontak is* **OR/*OF*** The coefficient of kinetic friction depends only on the type of materials used or the weight.✓ *Die kinetiese wrywingskoëffisiënt hang slegs af van die tipe materiaal gebruik of die gewig* (2)
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