Training and Consultancy
The path to enlightened education

Province of the EASTERN CAPE EDUCATION

SUBJECT: PHYSICAL SCIENCES

GRADE 12

AUTUMN CLASSSES

TEACHER AND LEARNER CONTENT MANUAL

Topics

Newton's laws of Motion

PHYSICAL SCIENCES PROGRAMME FOR 2024 AUTUMN CLASSES

PAPER	TOPICS	TOTAL MARKS	WEIGHTING
5 DAYS			
PAPER 1: PHYSICS	Newton's Laws of Motion (3 hours)	± 18	± 12%
TOTAL		**± 18**	**±12 %**
Pre-test and Post-test to be administered since it's a revision of Term 1			

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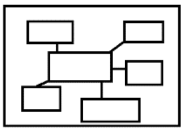
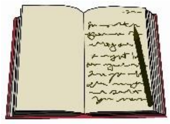
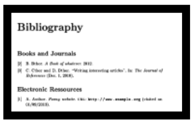
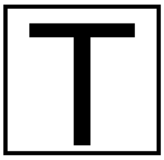
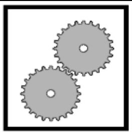
ICON DESCRIPTION

 MIND MAP	 EXAMINATION GUIDELINE	 CONTENTS	 ACTIVITIES
 BIBLIOGRAPHY	 TERMINOLOGY	 WORKED EXAMPLES	 STEPS

NEWTON'S LAWS: EXAMINATION GUIDELINES

Different kinds of forces: weight, normal force, frictional force, applied force (push or pull), tension (strings or cables)

- Define *normal force,* N, as the force or component of a force which the surface exerts on an object with which it is contact, and which is perpendicular to the surface.
- Define *frictional force, f,* as the force that opposes the motion of an object and which acts parallel to the surface.
  Define *static friction,* f_s, as the force that opposes the tendency of motion of a stationary object relative to a surface.
  Define *kinetic frictional,* f_k, as the force that opposes the motion of a moving object relative to the surface.
  Know that a frictional force:
    - Is proportional to the normal force.
    - Is independent of the area of contact.
    - Is independent of the velocity of motion.
- Solve problems using $f_s^{max} = \mu_k N$ where f_s^{max} is the maximum static frictional force and μ_s is the coefficient of static friction.
  NOTE:
    - If the force, F, applied to a body parallel to the surface does not cause the object to move, F is equal in magnitude to the static frictional force.
    - The static frictional force is a maximum (f_s^{max}) just before the object starts to move across the surface.
    - If the applied force exceed f_s^{max} , a resultant net force accelerate the object.
- Solve problems using $f_k = \mu_k N$, where f_k is the kinetic frictional force and μ_k the coefficient of kinetic friction.

Force diagrams, free-body diagrams

- Draw force diagrams.
- Draw free-body diagrams. (This is a diagram that shows the relative magnitudes and directions of the forces acting on a body/particle that has been isolated from its surroundings)
- Resolve two-dimensional forces (such as the weight on an object on an inclined plane) into its parallel (x) and perpendicular (y) components.
- Determine the resultant or net force of two or more forces.

Newton's first, second and third laws of motion.

- State Newton's first law of motion: A body will remain in its state of rest or motion at constant velocity unless a non-zero resultant/net force acts on it.
- Discuss why it is important to wear a seatbelt using Newton's first law of motion.
- State Newton's second law of motion: When a net force acts on an object, the object will accelerate in the direction of the net force and acceleration is directly proportional to the force and inversely proportional to the mass of the object.
- Draw force diagrams and free-body diagram for object that are in equilibrium or accelerating.
- Apply Newton's laws to variety of equilibrium and non-equilibrium problems including:
    - A single object:

- Moving on horizontal plane with or without friction
- Moving on an inclined plane with and without friction
- Moving in the vertical plane (lifts, rockets, etc)

  - Two-body systems (joined by a light inextensible string) by applying Newton's laws of motion separately to EACH of the bodies:
    - Both on the horizontal plane with and without friction
    - One on a horizontal plane with and 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 frictionless pulley.

- State Newton's third law of motion: When object A exert a force on object B, object B SIMULTANEOUSLY exert an oppositely directed force of equal magnitude on object A
- Identify action-reaction pairs.
- List the properties of action reaction pairs.

Newton's Law of Universal Gravitation

- State Newton's Law of Universal Gravitation: Each body in the universe attract every other body with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distances between their centres.
- Solve problems using $F = \frac{Gm1m2}{r2}$
- Describe weight as a gravitational force the earth exert on any object on or near its surface.
- Calculate weight using the expression w = mg.
- Calculate weight of an object on other planets with different values of gravitational acceleration
- Distinguish between *weight* and *mass.*
- Explain *weightlessness.*

IMPORTANT TERMS AND DEFINITIONS

T

NORMAL FORCE: N	The force or the component of a force in which a surface exerts on an object with which it is in contact, and that is perpendicular to the surface.
KINETIC FRICTIONAL FORCE: f_k	The force that opposes the motion of a moving object relative to a surface
STATIC FRICTIONAL FORCE: f_s^{max}	The force that opposes the tendency of a motion of a stationary object relative to a surface.
NEWTON'S FIRST LAW OF MOTION:	A body will remain in a state of rest or motion at constant velocity unless a non-zero resultant/net force acts on it.
NEWTON'S SECOND LAW OF MOTION:	When a net force acts on an object, the object will accelerate in the direction of the force and the acceleration is directly proportional to the force and inversely proportional to the mass of the object.
NEWTON'S THIRD LAW OF MOTION:	When object A exerts a force on object B, object B simultaneously exert oppositely directed force of equal magnitude on object A.
NEWTON'S LAW OF UNIVERSAL GRAVITATION:	Each body in the universe attracts every other body with the force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.
WEIGHT:	The gravitational force the Earth exerts on any object on or near its surface measured in Newton (N).
MASS:	The amount of matter in a body measured in kilogram (kg).
INERTIA:	The resistance of a body to change in its state of uniform motion or rest
WEIGHTLESSNESS:	The sensation experienced when all contact forces are removed

DATA FOR PHYSICAL SCIENCES GRADE 12
PAPER 1 (PHYSICS)

TABLE 1: PHYSICAL CONSTANTS/*TABEL 1: FISIESE KONSTANTES*

NAME/*NAAM*	SYMBOL/*SIMBOOL*	VALUE/*WAARDE*
Acceleration due to gravity *Swaartekragversnelling*	g	$9,8\ m\cdot s^{-2}$
Universal gravitational constant *Universele gravitasiekonstante*	G	$6,67 \times 10^{-11}\ N\cdot m^2\cdot kg^{-2}$
Radius of the Earth *Radius van die Aarde*	R_E	$6,38 \times 10^6\ m$
Mass of the Earth *Massa van die Aarde*	M_E	$5,98 \times 10^{24}\ kg$
Speed of light in a vacuum *Spoed van lig in 'n vakuum*	c	$3,0 \times 10^8\ m\cdot s^{-1}$

FORCE/*KRAG*

$F_{net} = ma$	$p = mv$
$f_s^{max} = \mu_s N$	$f_k = \mu_k N$
$F_{net}\Delta t = \Delta p$ $\Delta p = mv_f - mv_i$	$w = mg$
$F = G\frac{m_1 m_2}{d^2}$ or/*of* $F = G\frac{m_1 m_2}{r^2}$	$g = G\frac{M}{d^2}$ or/*of* $g = G\frac{M}{r^2}$

CONTENT

Key concepts

- Important definitions & Laws
- Free-body diagrams
- Calculations:
  - Normal force
  - Frictional force
  - Acceleration
  - Tension
  - Components of Force applied and gravitational force.
- Law of Universal Gravitation
  - Calculation of Gravitational force
  - Calculation of Gravitational acceleration

Quantity Name	Quantity Symbol	Unit Name	Unit Symbol
Normal force	F_N / N	Newtons	N
Frictional Force	f	Newtons	N
Kinetic Friction	f_k	Newtons	N
Maximum Static friction	f_s^{max}	Newtons	N
Tension	T	Newtons	N
Net Force	F_{net}	Newtons	N
Mass	m	Kilograms	Kg
Acceleration	a	Metres per second squared	$m.s^{-2}$
Coefficient of friction	µ	No unit	

FRICTION FORCE AND NORMAL FORCE

NORMAL FORCE (F_n / N)

The force or the component of a force in which a surface exerts on an object with which it is in contact, and that is perpendicular to the surface.

- **Normal force** is the force exerted by a flat surface on an object with which it is in contact.
- Always acts perpendicular (at right angle, 90^0) to the surface.
- **Normal force** equal to the gravitational force F_g, or the net of F_g and other forces acting perpendicular to the surface.

FRICTIONAL FORCE (f)

- **Frictional Force** is caused by one surface tending to move over another, while in contact

- Resist the movement of an object.

  - Prevents it from moving.
  - Or makes it move slower.

KINETIC FRICTIONAL FORCE ($\boldsymbol{f_k}$)

$$f_k = \mu_k N$$

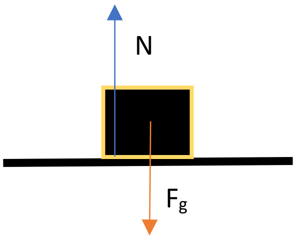
$f_k - kinetic\ frictional\ force\ (N)$
$\mu_k - coefficient\ of\ kinetic\ frictional\ force\ (no\ unit)$
$N - Normal\ force (N)$

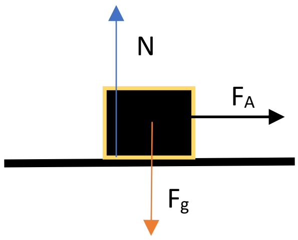
MAXIMUM STATIC FRICTIONAL FORCE ($\boldsymbol{f_s^{max}}$)

$$f_s^{max} = \mu_k N$$

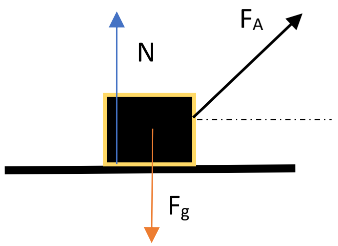
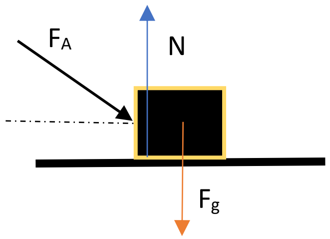
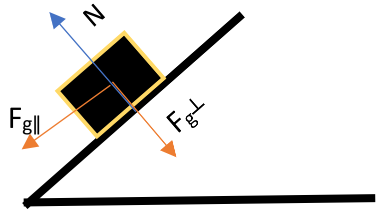
$f_s^{max} - Static\ frictional\ force\ (N)$
$\mu_s - coefficient\ of\ Static\ frictional\ force\ (no\ unit)$
$N - Normal\ force (N)$

Normal force qual to gravitational force or the net of F_g and other forces acting perpendicular to the surface.



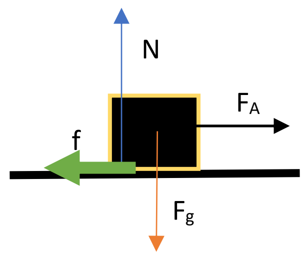
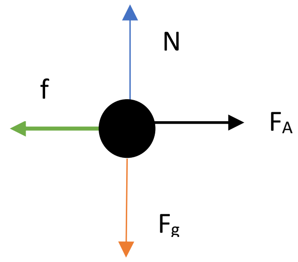
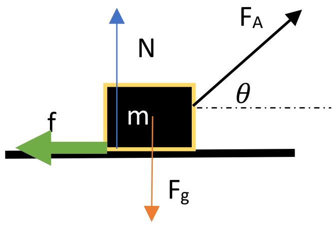
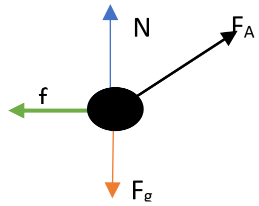
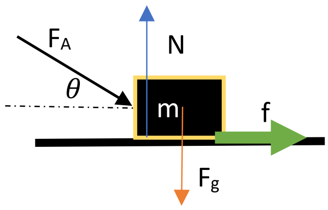
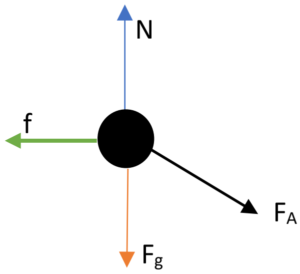
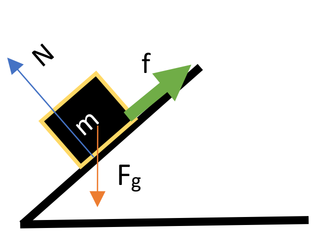
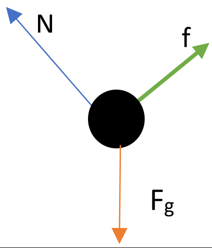
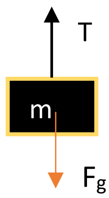
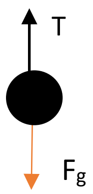


$$F_{net} = ma = 0$$
$$N + \left(-F_g\right) = 0$$
$$N = F_g$$
$$N = mg$$
$$f_k = \mu_k N$$
$$f_k = \mu_k mg$$

PULLING at an angle	PUSHING at an angle	**For an object on the inclined plane Normal force will equal the magnitude of perpendicular component of weight (Fg┴)**
 $F_{net} = ma = 0$ $N + F_y + (-F_g) = 0$ $N = F_g - F_y$ $N = mg - F_a sin\theta$ $f_k = \mu_k N$ $f_k = \mu_k(mg - F_a sin\theta)$ • When the angle is increased, the normal will decrease, hence the frictional force will also decrease. • When the angle is decreased, the normal force will increase, hence the frictional force will also increase.	 $F_{net} = ma = 0$ $N + (-F_y) + (-F_g) = 0$ $N = F_g + F_y$ $N = mg + F_a sin\theta$ $f_k = \mu_k N$ $f_k = \mu_k(mg - F_a sin\theta)$ • When the angle is increased, the normal will increase, hence the frictional force will also increase. • When the angle is decreased, the normal force will decrease, hence the frictional force will also decrease.	 $F_{net} = ma = 0$ $N + (-F_{g\perp}) = 0$ $N = F_{g\perp}$ $N = F_g cos\theta$ $N = mgcos\theta$ $f_k = \mu_k N$ $f_k = \mu_k(mgcos\theta)$ • When an angle is increased, the normal force will decrease, hence the frictional force will also decrease. • When an angle is decreased, the normal force will increase, hence the frictional force will also increase.
Any change made on an angle will affect the co-efficient of kinetic friction		

FORCE DIAGRAM AND FREE BODY DIAGRAM

- **A free body diagram** is a picture of an object of interest drawn as a dot and all the forces acting on it are drawn as arrows pointing away from the dot (**in a free body diagram the object is represented by a dot**)
- **Force diagram**: force diagram is a representation of all the forces acting on the object. It is drawn as an arrow.

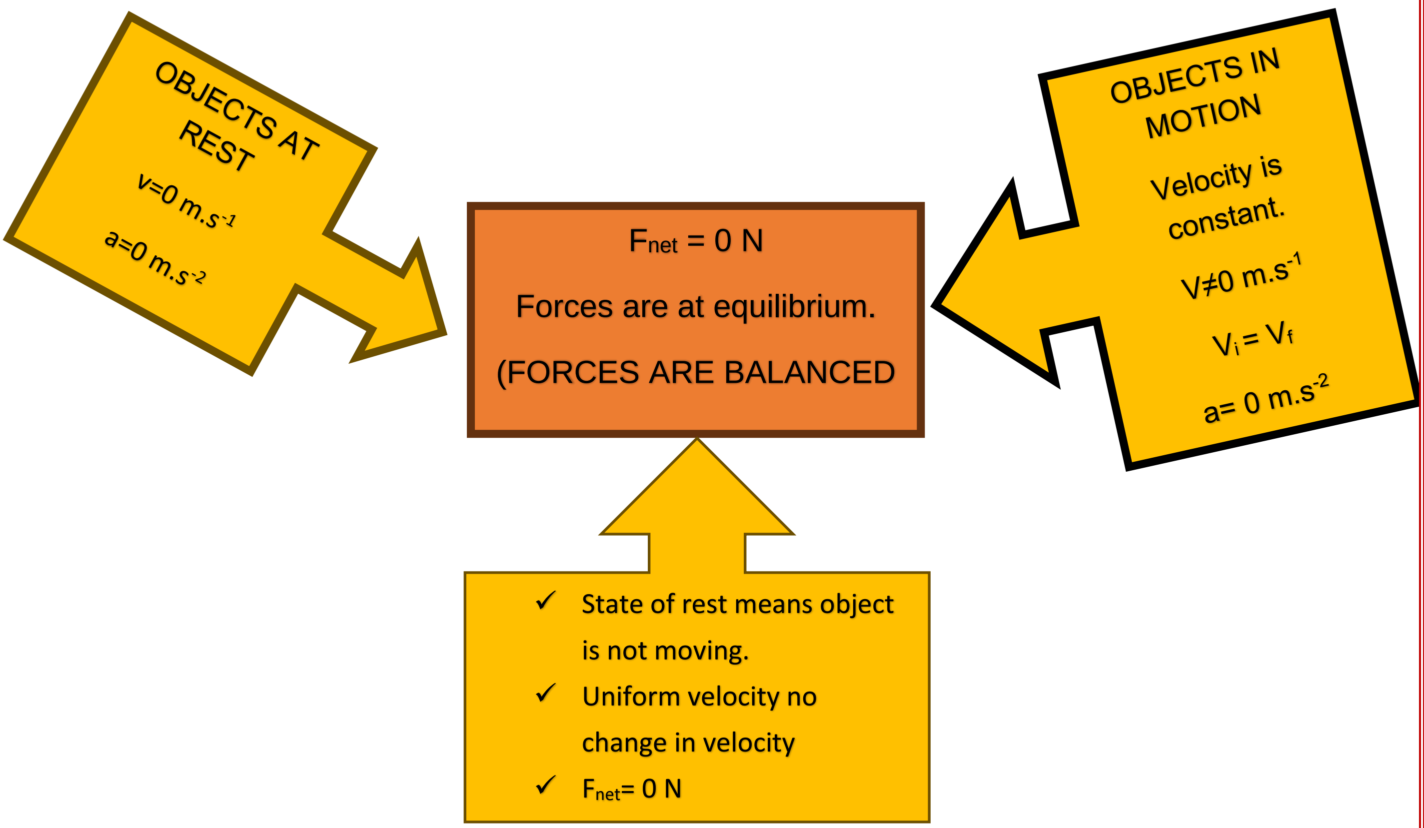
Examples	FORCE DIAGRAM	FREE BODY DIAGRAM
EXAMPLE 1 Force **A** is applied to the right, on an object resting on a rough surface.		
EXAMPLE 2 Force **A** is exerted on an object, mass **m** and pulls the object at an angle, **ɵ** to the horizontal along a rough surface.		
EXAMPLE 3 Force **A** is applied on an object, mass **m** and pushes the object at an angle, **ɵ** to the horizontal surface and experiences frictional force **f**.		
EXAMPLE 4 Object m, resting on an inclined plane and experiences a frictional force **f**		
EXAMPLE 5 Object **m** is suspended on a ceiling with a light inextensible string.		

NB: More examples must be done on an inclined plane and two-body systems (joined by a light inextensible string).

NEWTON'S LAWS OF MOTION

NEWTON'S FIRST LAW

A body will remain in its state of REST or motion at CONSTANT VELOCITY unless a non-zero resultant/net force act on it.



Newton's first law is sometimes referred as **INERTIA**.

Inertia: Is a tendency of an object to resist any change in its state of rest or uniform motion.

Application: The importance of wearing seatbelts:

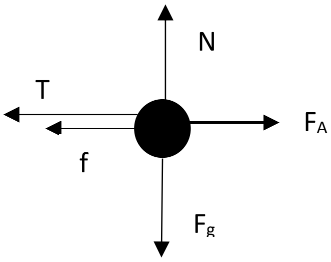
- We wear seat belts in cars. Why?
- This is to protect us when the car is involved in an accident. If a car is travelling at 120 $km.h^{-1}$, the passengers in the car are also travelling at 120 $km.h^{-1}$ due to inertia.
- When the car suddenly stops a force is exerted on the car (making it slow down), but not on the passengers. The passengers will carry on moving forward at –120 $km.h^{-1}$ according to Newton first law.
- If they are wearing seat belts, the seat belts will stop them and therefore prevent them from getting hurt.

EXAMPLE 1

Two objects are being pulled over a straight rough horizontal surface with a force of 900 N. The mass of object **A** is 130 Kg, and the mass of object **B** is 95 Kg. The two objects are connected by a light inextensible rope.

The two objects move at constant velocity.

1.1 Draw a labelled free-body diagram to show all the forces acting on object **A**. (5)



F_A	✓
T	✓
N	✓
Fg	✓
f	✓

1.2 Calculate the magnitude of the kinetic frictional force between object **A** and the surface if the coefficient of kinetic friction is 0.45. (3)

$$f_k = \mu_k N ✓$$
$$f_k = \mu_k mg$$
$$f_k = (0.45)(130)(9.8) ✓$$
$$f_k = 573.3\ N ✓$$

1.3 Name and state the Law that is relevant for the scenario above. (3)

NEWTON'S FIRST LAW

A body will remain in its state of REST or motion at CONSTANT VELOCITY unless a nonzero resultant/net force act on it.

NEWTON'S SECOND LAW OF MOTION:

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

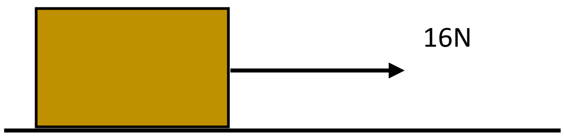
$F_{net} = ma$

- Directly proportional means as the acceleration increases also the F_{net} increases or acceleration decreases also the F_{net} decreases.
- a α F_{net}

- Inversely proportional means that as the acceleration increases the mass decreases.
- $a = \frac{1}{m}$

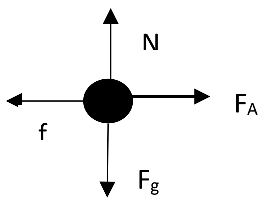
EXAMPLE 2

A 5kg block is placed on a horizontal surface. A horizontal force of 16 N is applied on the block, the block accelerates to the right as shown in the diagram below.



A frictional force between the block and the surface is 5 N

2.1 Draw a free-body diagram of all forces acting on the block as it accelerates (4)



F_A	✓
N	✓
Fg	✓
f	✓

2.2 State the law in words that can be used to explain why the block is accelerating (2)

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

2.3 Calculate the acceleration of the block.

$F_{net} = ma$✓

$F_A - T = ma$

$16 - 5 = 5a$✓

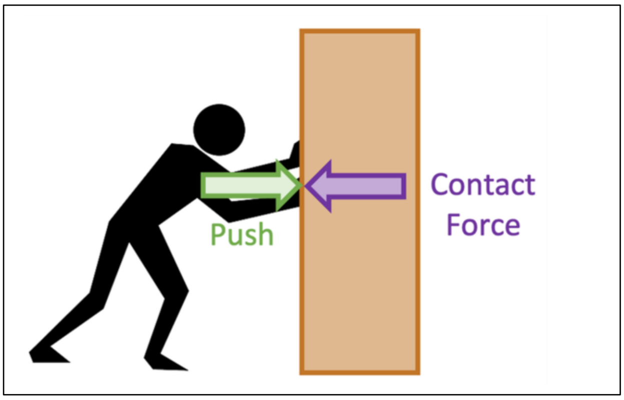
$a = 2.2\ m.s^2$✓

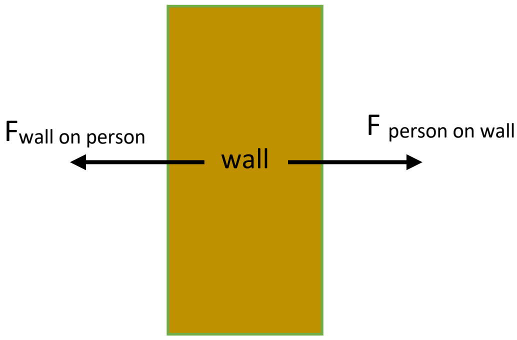
2.4	The magnitude of the force is now increased to 25 N. Explain how the magnitude of acceleration will be affected	(3)
	F_{net} = ma **According to Newton's second law F_{net} is directly proportional to acceleration. ✓** **Acceleration will increase, an increase in the net force will increase acceleration since ✓**	

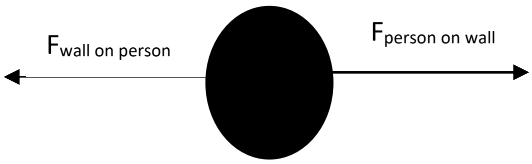
NEWTON'S THIRD LAW

When object A exert a force on object B, object B SIMULTENEOUSLY exert an oppositely directed force of equal magnitude on object A.

Person (OBJECT A) Wall (OBJECT B)







PROPERTIES OF ACTION-REACTION PAIRS

They are not balanced as the act on the different objects.

- Two forces of Action and Reaction have the same **magnitude**, but act in opposite directions.
- They act on different objects.
- They act along the same line.
- They arise from the same interaction.
- They occur simultaneously.

Newton's law of Universal Gravitation

Each body in the universe attracts every other body with the force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

$$F = \frac{Gm_1m_2}{r^2}$$

- The force of attraction between two objects is directly proportional to the product of their masses.

$$F \propto m_1m_2$$

- And inversely proportional to the square of the distance between their centres.

$$\mathrm{F} \propto \frac{1}{r^2}$$

ACTIVITY 1 A 10 marks, 10 minutes

1.1. Define the following terms:

1.1.1	Normal force	(2)
1.1.2	Static Frictional force	(2)
1.1.3	Kinetic frictional force	(2)

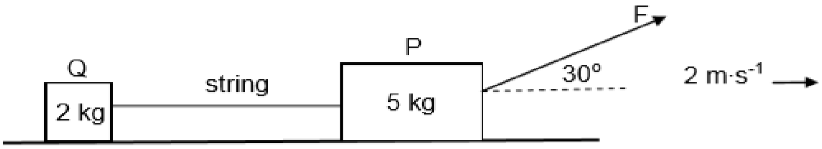
1.2. State the following Newton's Laws

1.2.1	Newton's First Law of Motion	(2)
1.2.2	Newton's Law of Universal Gravitation	(2)

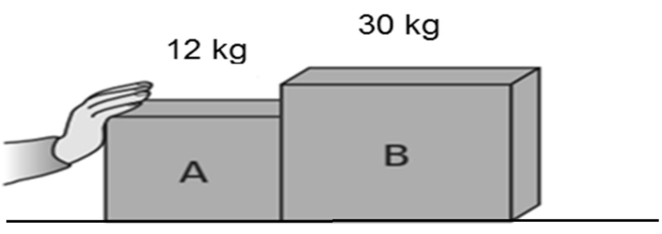
[10]

ACTIVITY 1 B FREE-BODY DIAGRAM

1.3 For each of the following draw a labelled FREE-BODY DIAGRAM.

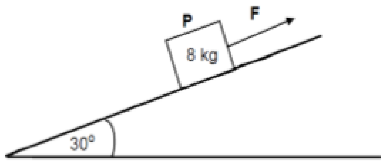


1.3.1	For 2 Kg block	(4)
1.3.2	For 5 Kg block	(5)



1.3.3 For 12 Kg block (5)

1.3.4



Smooth Surface (3)

[17]

ACTIVITY 1 C MULTIPLE CHOICE

10 marks, 10 minutes

1.4. Which of the following best illustrates balanced forces?

A. A person lifting a heavy object from the ground
B. A big rock free-falling to the ground
C. A light stationary object
D. A force of a box on the earth and a force of the earth on the box (2)

1.5. A constant net force acts on an object moving in a straight line. Which ONE of the following quantities associated with the object will remain constant during the motion?

A. Velocity
B. Momentum
C. Acceleration
D. Kinetic energy (2)

1.6. Which Law best describe why a driver and passenger should wear a seatbelt while driving is:

A. Newton's First Law
B. Newton's Second Law
C. Newton's Third Law
D. Newton's Law of Universal Gravitational. (2)

1.7 An object mass m_2 attracts another object mass m_1 with a force **F**. If the mass m_2 is doubled, the force m_2 exerts on m_1 will be …

A. ¼ F
B. F
C. 2 F
D. 4 F (2)

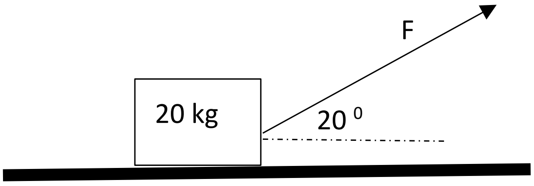
1.8 The weight of an object on the surface of the Earth is w. What will be the weight of the object on the surface of another planet of the SAME mass as that of the Earth, but **TWICE** the radius of the Earth?

A. ¼ w
B. ½ w
C. 2 w
D. 4 w (2)

[10]

ACTIVITY 2 15 marks, 15 minutes

The force F is applied at an angle of 20^0 to the horizontal, on a crate as shown in the diagram below.



A constant frictional force of 3 N acts between the surface and the crate. The coefficient of kinetic friction between the crate and the surface is 0,2

2.1 Draw a labelled free-body diagram showing ALL the forces acting on the crate. (4)

2.2 Calculate the magnitude of the:

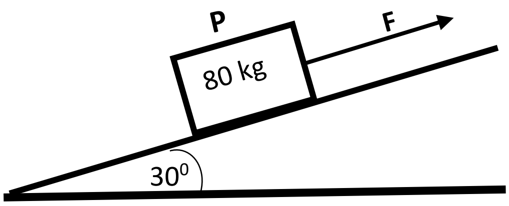
2.2.1 Normal force acting on the crate. (3)
2.2.2 Force F. (4)
2.2.3 Acceleration of the crate (4)

[15]

ACTIVITY 3 12 marks, 12 minutes

An 8 kg block, **P**, is being pulled by constant force **F** up a rough inclined plane at an angle of 30o to the horizontal, at **CONSTANT SPEED**.

Force **F** is parallel to the inclined plane, as shown in the diagram below.



3.1 Draw a labelled free-body for block **P**. (4)

3.2 The kinetic frictional force between the block and the surface of the inclined plane is 20, 37 N.

Calculate the magnitude of force F. (4)

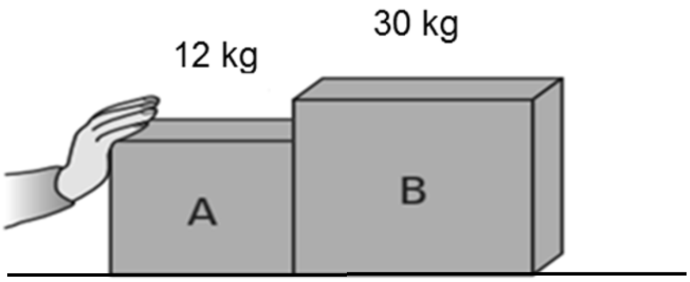
3.4 Force F is now removed, and the block **ACCELERATES** down the inclined plane. The kinetic frictional force remains 20, 37 N.

Calculate the acceleration of the block. (4)

[12]

ACTIVITY 4 19 marks, 19 minutes

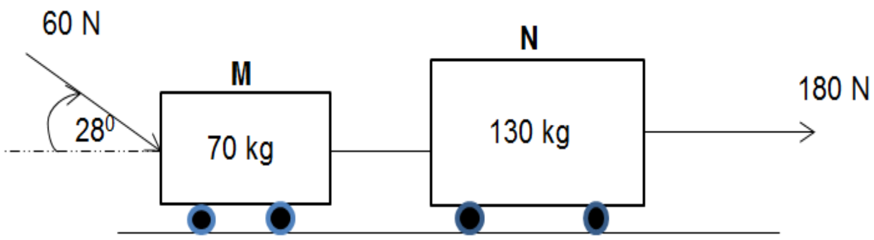
Crate **A** and crate **B**, of different masses, are placed next to each other on a horizontal rough surface. A hand pushing crate **A** causes both crates to accelerate at **2,3 m.s^{-2}** to the right. Crate **B** experiences a frictional force **of 25,3 N**



4.1 State Newton's *Third Law* of Motion in words. (3)

4.2 Calculate the force exerted by crate **B** on crate **A.** (6)

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



The frictional force experienced by trolley **M** is 6,4 N and that of trolley **N** is 8,58 N.

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

4.3.2 If the system accelerates at 1,09 m.s^{-2}, calculate the tension (**T**) in the String. (4)

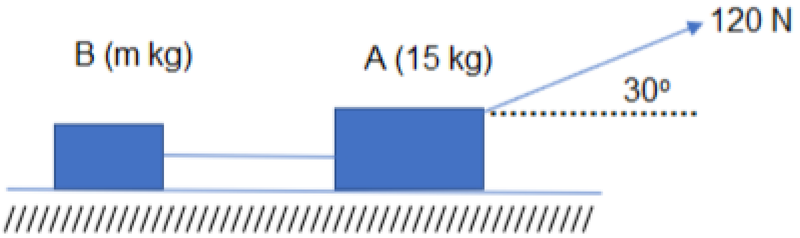
4.4 If Sipho's pulling force is now applied at an angle of 60° with the horizontal, what will happen to the frictional force experienced by trolley **N**? Write only INCREASES, DECREASES or REMAINS THE SAME (1)

4.5 Explain your answer in QUESTION 4.4. (3)

[19]

ACTIVITY 5 22 marks, 22 minutes

Two blocks, **A** of mass 15 kg and **B** of unknown mass, **m** kg, are connected by a light inextensible (inelastic) string on a rough surface. A force of magnitude 120 N is applied to block **A** at an angle of 300 to the horizontal as shown in the diagram below.



5.1 The coefficient of friction for the surface, for both objects is 0,20 and the system accelerates to the right at 2,08 $m \cdot s^{-2}$.

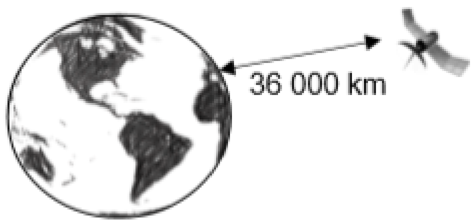
5.1.1 State Newton's Second Law of motion in words. (2)

5.1.2 Draw a fully labelled free-body diagram of ALL the forces acting on block **A**. (5)

5.1.3 Show that the frictional force experienced by block **A**, while accelerating is 17,4 N. (4)

5.1.4 Calculate the tension force in the string between block **A** and **B**. (4)

5.2 Consider a satellite with mass 1 200 kg orbiting Earth. The distance between the centre of the satellite and the surface of the earth is 36 000 km.

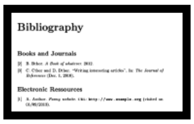


5.2.1 State Newton's universal gravitational law, in words. (2)

5.2.2 Calculate the magnitude of the force that the Earth exerts on the satellite. (4)

5.2.3 How will the force that the satellite exerts on the Earth compared to the answer to QUESTION 5.2.2? Write only GREATER THAN, LESS THAN or EQUAL TO. (1)

[22]



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