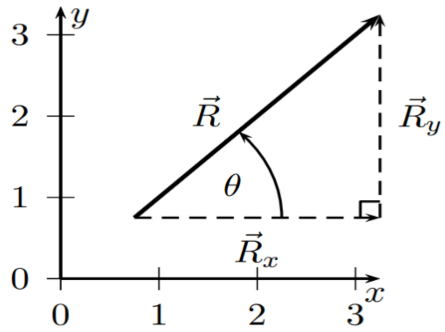
SUBJECT and GRADE	Physical Sciences; Grade 11
TERM 1	Week 3
TOPIC	Forces and vectors in two dimensions
AIM OF LESSON	**At the end of this lesson you should be familiar with the following:** Vectors in two dimensions • Resolve a vector R into its horizontal (R_x) and vertical (R_y) components. • Using $R_x = R\cos\theta$ and $R_y = R\sin\theta$, where θ is the angle between r and the x axis. Newton's laws • Define normal force, N. • Define frictional force, f. • Know that a frictional force is: - proportional to the normal force; and - independent of the area of the surfaces that are in contact with each other.
RESOURCES	**Paper-based / physical resources** • Prescribed CAPS Physical Sciences textbook, as well as Siyavula Grade 11 Physical Sciences resource (learner book, pg. 58 - 123); Physical Sciences CAPS document (pg. 61 - 63); and Grade 11 Physical Sciences Examination Guideline (pg. 7). *(Additional subject-related material, e.g. Mind the Gap, Science Clinic, Answer Series, etc.)*. • Scientific calculator, pen and pencil.

	Digital resources • 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=10rwbv1gMWQ; https://www.youtube.com/watch?v=ml4NSzCQobk • Mind the Gap: https://www.education.gov.za/Curriculum/LearningandTeachingSupportMaterials(LTSM)/MindtheGapStudyGuides.aspx
INTRODUCTION	Use the following link to enhance your background knowledge on the topic of forces covered in the previous lessons, which are summarized and shown in the accompanying video. https://www.youtube.com/watch?v=10rwbv1gMWQ
CONCEPTS AND SKILLS	***This section must be read in conjunction with the CAPS, pg. 61 - 63.*** **1. COMPONENTS OF VECTORS**

In the previous lesson *(concerning vector addition)* we learnt that a number of vectors acting together can be combined to give a single vector *(resultant)*. The single vector can therefore be broken down into a number of vectors, which when added together result in the original vector once again. These vectors which sum to the original are called components of the original vector. The process of breaking a vector into its components is called resolving into components.



We can make use of a right-angled triangle when resolving vectors into components that are parallel to the x- and y-axes. We can therefore use trigonometric relationships to determine the magnitudes of the components.

From the triangle in the diagram above we know that:

$$\cos(\theta) = \frac{R_x}{R}$$
$$\frac{R_x}{R} = \cos(\theta)$$
$$R_x = R\cos(\theta)$$

and

en

$$\sin\theta = \frac{R_y}{R}$$
$$\frac{R_y}{R} = \sin(\theta)$$
$$R_y = R\sin(\theta)$$

Thus, we can deduce that:

$R_x = R\cos(\theta)$ and $R_y = R\sin(\theta)$

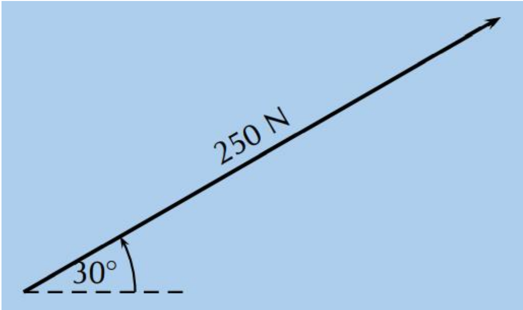
(Please note: The angle is measured counterclockwise from the positive x-axis).

EXAMPLE: Resolving a vector into its components

A force of 250N acts at an angle of 30° to the positive x-axis. Resolve this force into components parallel to the x- and y-axes.

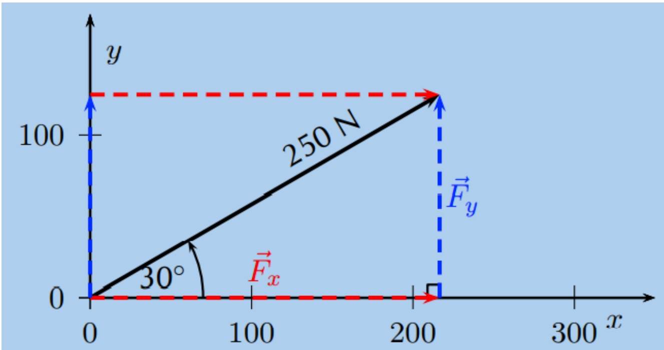
SOLUTION:

Step 1: Draw a rough sketch of the original vector.



Step 2: Determine the vector components.

Next, we resolve the force into components parallel to the axes. Since these directions are perpendicular to one another, the components form a right-angled triangle with the original force as its hypotenuse.



Notice how the two components acting together give the original vector as their resultant.

Step 3: Determine the magnitudes of the component vectors.

Now we can use trigonometry to calculate the magnitudes of the components of the original displacement:

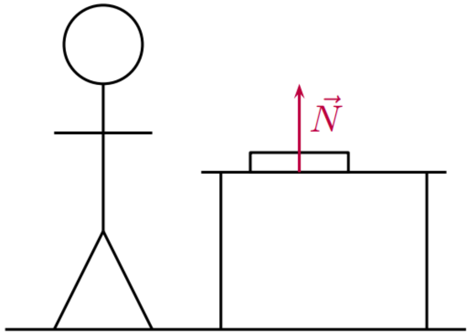
$F_y = 250 \sin(30^\circ) = 125$ N and $F_x = 250 \cos(30^\circ) = 216{,}5$ N

(Remember F_x and F_y are the magnitudes of the components. $\vec{F}_x$ is in the positive x-direction and $\vec{F}_y$ is in the positive y-direction).

2. DIFFERENT FORCES

2.1 NORMAL FORCE

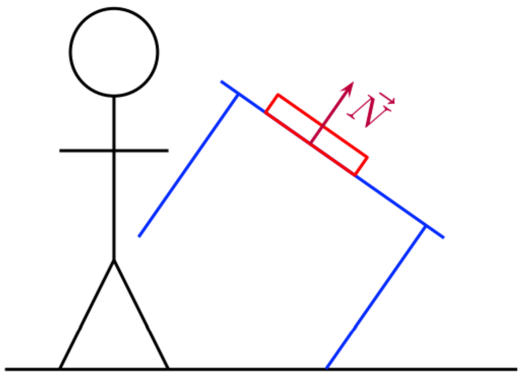
Definition: The normal force, $\vec{N}$, is the force exerted by a surface on an object in contact with it.



- Various forces act onto an object which is placed on a surface, for example putting a book on a table. We know that if the table was not there the book would fall to the floor due to the force of gravity acting on it. The table is therefore exerting a force on the book and stops the book from falling on the floor. The force exerted by the table on the book balances out the force of gravity. Both forces should therefore be vectors and the same in magnitude, even though they are applied onto the book in opposite directions.
- Gravity pulls a person towards the earth, but when you are standing on the ground something *(another force)* must be balancing it. *(However, if you put a brick on water it will sink because nothing else balances the gravitational force)*. We call the force that any surface exerts to balance the forces on an object in contact with it the normal force.
- The normal force is a force that acts on the object as a result of the interaction with the surface and is perpendicular to the surface.
- PLEASE NOTE: If we tilt the table slightly the direction of the gravitational force has not changed, but the direction of the normal force will change, because the normal force is always perpendicular *(at a right angle)* to the surface. *(Thus, the normal force is not always directly opposite to gravity)*.

2.2 FRICTION

Definition: Frictional force is the force that opposes the motion of an object in contact with a surface.



- Friction arises because of surfaces interacting *(being in contact)* with one another and moving relative to each other. *(Frictional forces act parallel to surfaces)*.
- When the surface of one object slides over the surface of another, each body *(object)* exerts a frictional force on the other. Common examples include the following:
  - When a book slide across a table, both the book and the table exert a frictional force onto each other.
  - A box sliding on a surface eventually come to a stop due to friction opposing the motion of the box. *(Two objects in contact and their motion relative to one another)*.
  - Rubbing your hands when it is cold. The heat generated is through friction.
  - Using sandpaper to smoothen surfaces of metal and wood. If you rub sandpaper the small bumps can be felt, which will slot into any groove of the surface on which the sandpaper is applied.
- The magnitude of the frictional force depends on the surface and the magnitude of the normal force. Different surfaces will give rise to different frictional forces, even if the normal force is the same. Frictional forces are proportional to the magnitude of the normal force. *($F_{friction} \propto N$)*

Table: 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

Extracted and summarized from: Siyavula Grade 11 Physical Sciences resource (learner book, pg. 58 - 123); Physical Sciences CAPS document (pg. 61 - 63); and Grade 11 Physical Sciences Examination Guideline (pg. 7).

EXERCISES FOR CONSOLIDATION PURPOSES

Please use ample time to complete the following activities (questions 1 to 4), 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 – 1.4), for example 1.1.11 E.

1.1 Which ONE of the following pairs of physical quantities is vector quantities?

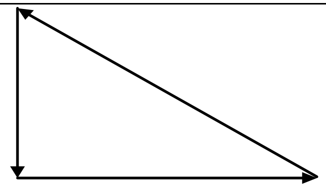
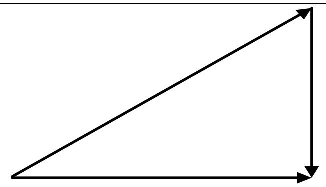
A Force and distance.

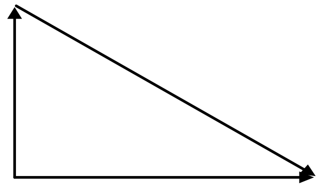
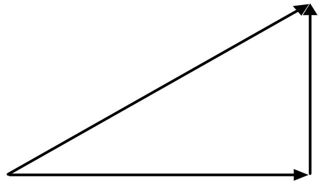
B Velocity and speed.

C Charge and electric field.

D Electric field and force. (2)

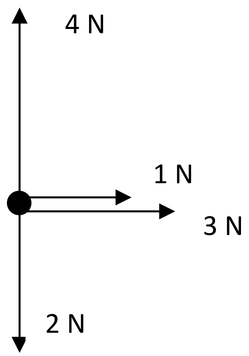
1.2 Which ONE of the following vector diagrams represents three forces acting on an object simultaneously while the object moves at CONSTANT VELOCITY?

A  B 

C  D 

(2)

1.3 Four forces act on a point, as indicated in the accompanying diagram.



The magnitudes of the components of the resultant (net) force in the horizontal (F_X) and vertical (F_Y) directions are …

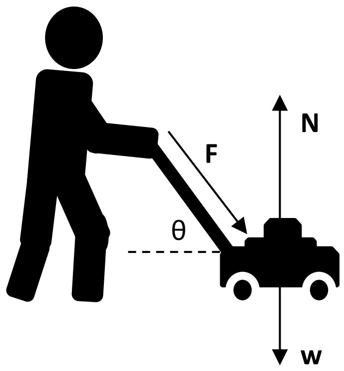
A F_X = 3 N and F_Y = 6 N.

B F_X = 1 N and F_Y = 4 N.

C F_X = 2 N and F_Y = 2 N.

D F_X = 4 N and F_Y = 2 N. (2)

1.4 A lawnmower is pushed across the ground with a force of **F** at an angle of θ with the horizontal. The weight of the lawnmower is **w**.



The normal force, in **N**, on the lawnmower is … (2)

A W

B $w + F_Y$

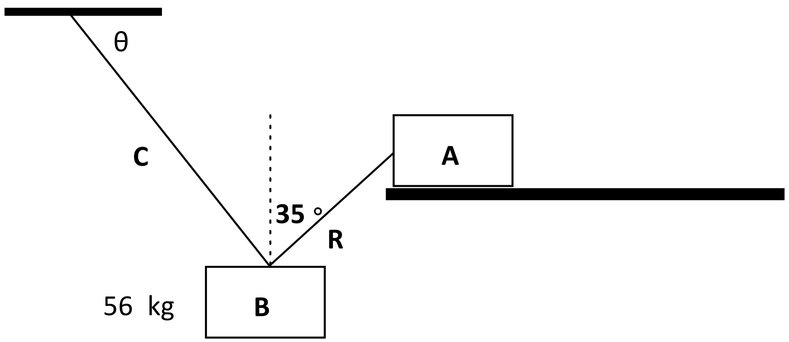
C $w - F_Y$

D $w + F_X$

[8]

QUESTION 2

Block **A**, which is at rest on a horizontal rough surface, is used as an anchor to hold block **B**, with a mass of 56 kg, in the air at a certain height above the ground. The two blocks are connected with rope **R**, which makes an angle of 35° with the vertical. Block **B** is suspended from the ceiling with cable **C**. Refer to the diagram below.



Block **A** experiences a frictional force of magnitude 200 N. The system is stationary.

2.1 Define the term *resultant vector*. (2)

2.2 What is the magnitude of the resultant force acting on block **B**? (1)

2.3 Draw a labelled free-body diagram indicating all the forces acting on block **B**. (3)

2.4 Determine the horizontal component of the force in rope **R**. (1)

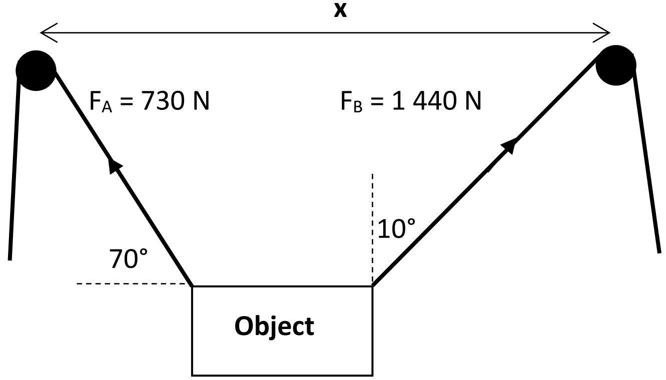
2.5 Calculate the vertical component of the force in cable **C**. (4)

2.6 Calculate the angle θ between the cable and the ceiling. (2)

[13]

QUESTION 3

A heavy object is lifted using two ropes and two pulleys, as shown in the diagram below. The two pulleys are a distance **x** apart. The force F_A, in rope **A**, is 730 N and the force F_B, in rope **B**, is 1440 N. Rope **A** makes an angle of 70° with the horizontal and rope **B** makes an angle of 10° with the vertical.



3.1 Define the term *resultant vector*. (2)

3.2 Explain why the vector diagram of force F_A, force F_B and the weight will NOT be a closed vector diagram. (2)

3.3 Calculate the:

3.3.1 Vertical component of F_A (2)

3.3.2 Horizontal component of F_A (2)

3.4 Calculate the maximum weight that force F_A and force F_B will be able to lift from the ground. Show ALL calculations. (4)

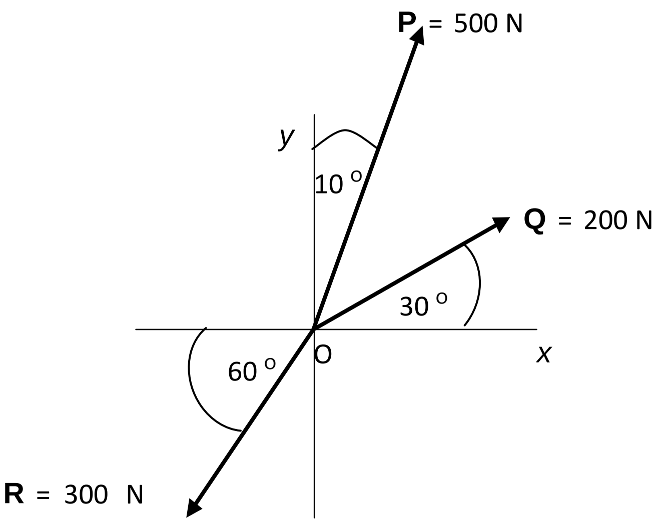
3.5 Explain why the rope and pulley system will be less effective if the distance **x** between the pulleys is increased. (2)

[14]

QUESTION 4

Three forces, **P**, **Q** and **R**, of magnitudes 500 N, 200 N and 300 N respectively, act on a point **O** in the directions shown in the diagram below.

The forces are NOT drawn to scale.



4.1 Refer to the information in the diagram above and give a reason why forces **P**, **Q** and **R** are classified as vectors. (2)

4.2 Determine the magnitude and direction of the resultant force, either by CALCULATION or by ACCURATE CONSTRUCTION AND MEASUREMENT. *(Use scale 10 mm = 50 N)*. (8) **[10]** **TOTAL = 45** **Answers to the above questions are available in this link.** **https://drive.google.com/file/d/13uIojxNyYzZNtNPPtotCCZxiDGuEhl68/view?usp=sharing**	
CONSOLIDATION	**Summary of lesson content, which you should be familiar with at this stage:** **Resolution of a vector into its horizontal and vertical components** • Drawing vector diagrams on the Cartesian plane showing vector magnitude and the angle (θ) between the vector and the x-axis. • Calculating the resultant x-component by using $R_x = R\cos(\theta)$. • Calculating the resultant y-component by using $R_y = R\sin(\theta)$. **Different kinds of forces** • Define normal force (N), as the force *(or the component of a force)* which a surface exerts on an object in contact with it. • The normal force acts perpendicular to the surface irrespective of whether the plane is horizontal or inclined. For horizontal planes the only forces perpendicular to the plane should be the weight (W), and the normal force (N). All other forces should be parallel to the plane. For inclined planes the only forces perpendicular to the plane is the component of weight (Wcosθ), and the normal (N). All other forces should be parallel to the plane. • Define frictional force (f), as the force that opposes the motion of an object and which acts parallel to the surface. • Frictional force is: (1) proportional to the normal force; and (2) independent of the area of the surfaces that are in contact with each other.

VALUES / APPLICATIONS IN PRACTICE	**Value of using ‘*resolution of vector components*’ *applications* for the purpose of daily activities and industrial applications.** By now we need to know that vectors are used to describe anything that has both direction and magnitude. Vectors are used in numerous applications related to STEM *(Science, Technology, Engineering and Mathematics)*, as well as in our daily lives. Consider the following examples and also visit the accompanying link to watch the video which brings vector components into perspective of everyday life. • Vectors are used to gain information regarding the position of individuals, objects and places *(e.g. GPS)*. *(Also describing objects acting under the influence of an external force)*. • Sport players *(e.g. American football-, rugby-, soccer- and netball players)* use vectors to ensure accurately passing the ball to their teammates. *(Coaches and TV-referees use specialised camera equipment for vector measurement and calculation purposes)*. • Airports, train stations, bus terminals and space flights all engaged in practices involving vector applications. *Example: Consider a commercial airplane in flight, which encounters a strong tailwind that pushes the plane off course. Principles underpinning vector addition (i.e. resolution of vector components) enable aviation practitioners to calculate the resultant vector for the most safest speed, direction and position which should be maintained by the airplane. Another example includes air force pilots who rely on vector calculations to launch missiles, or even intercept and destroy missiles approaching them.* • Results obtained by using ‘resolution of force vectors’ applications help us to study, analyse and understand the causes of motion separately in vertical, mediolateral, and anteroposterior *(front- and backward)* directions. This is particularly important in the medical field and sport biomechanics, since it reinforces understanding of human muscular functions in neuromotor tasks, such as activities which include walking, running, jumping, throwing, postural stability, etc. • Newton's laws of motion *(which will be covered in the following lessons)* are all directly linked with vector relationships that describe the motion of objects under the influence of external forces, for example, a stone falling towards the ground, or a rocket launched into space. **A look into real-life applications of vector components** https://www.youtube.com/watch?v=ml4NSzCQobk