KWAZULU-NATAL

DEPARTMENT OF EDUCATION

LEARNER SUPPORT DOCUMENT

PHYSICAL SCIENCES

GRADE 11

Table of contents

Vectors in One Dimension – Revision

Vector – physical quantity having magnitude and direction.

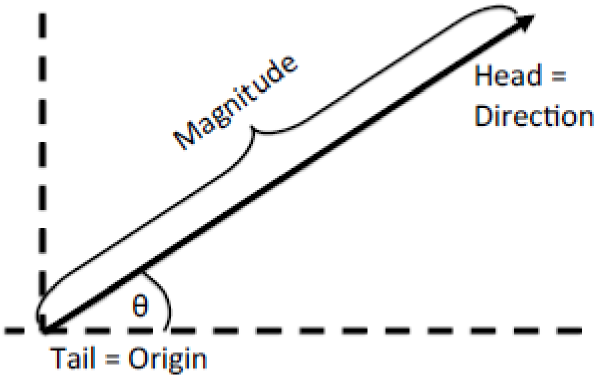
Scalar – physical quantity having magnitude only.

Examples:

Vector	Scalar
Force	Time
	Energy
Weight	Mass
Velocity	Speed
Displacement	Distance
Acceleration	

Graphical Representation of a vector

- Vector is represented by an arrow
- The **length of an arrow** represents the **size (magnitude)** of the vector
- The **arrow-head** represents the **direction of the vector**.



Direction of a horizontal or vertical vector

A positive sign (+) or a negative sign (–) is used to indicate the direction of a vector that are either horizontal or vertical. For each example you must select the sign.

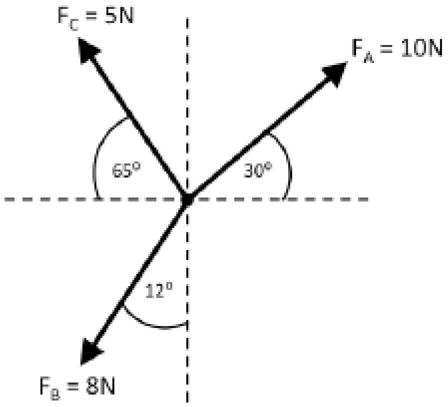
Examples

a) right is +  5 N

b) left is – ← - 3 N

Three methods to describe the direction of a vector that is not horizontal or vertical

On a graph



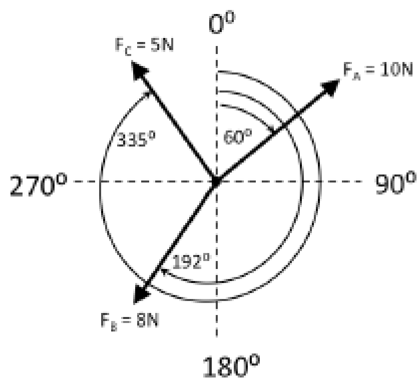
F_A : 10 N at 30° above the positive x- axis (horizontal axis)

F_B : 8 N at 12° left of the negative y- axis (vertical axis)

F_C : 5 N at 65° above the negative x- axis (horizontal axis)

Bearing

- Only for vectors in the horizontal plane i.e parallel to the surface of the Earth
- Use North as 0° and always measure **clockwise**

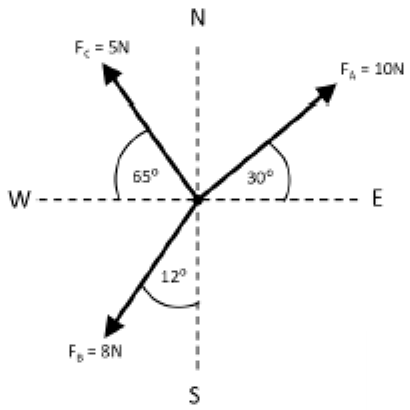


F_A : 10 N on a bearing of 60°

F_B : 8 N on a bearing of 192°

F_C : 5 N on a bearing of 335°

Compass (Cardinal points or directions)



F_A : 10 N at 30° North of East

F_B : 8 N at 12° West of South

F_C : 5 N at 65° North of West

RESULTANT OF VECTORS

Define a resultant as the vector sum of two or more vectors, i.e. a single vector having the same effect as two or more vectors together.

- Resultant vector is greatest when vectors are in the same directions
- Resultant vector is smallest when vectors are in the opposite directions

1. Two vectors acting in the same direction :(one dimension)

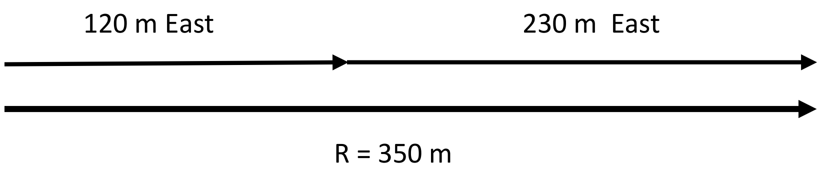
A girl walks 120m due East and then 230m in the same direction. What is her resultant displacement?

By calculation:

Sign of direction: Take to East to be +

R = 120m + 230m = 350m East

By construction:

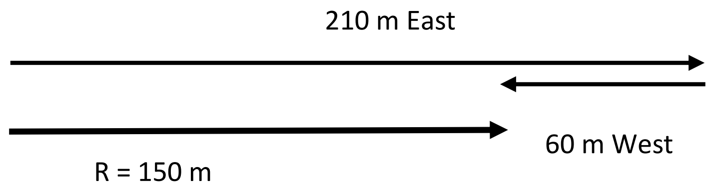


2. Two vectors acting in opposite direction (one dimension)

A boy walks 210m due East. He then turns and walk 60m due West. Determine his resultant displacement.

By calculation: (taking East as positive)

R = 210m + (- 60m) = 150m East



3. Multiple vectors acting in different directions (one dimension)

Determine the resultant(net) force when 8 N force acts to the right, a 10 N force acts to the right, a 25 N force acts to the left and a 12 N force acts to the left

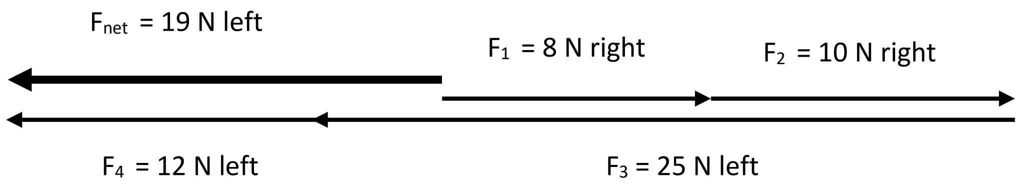
Let to the right be **positive**

$$F_{net} = F_1 + F_2 + F_3 + F_4$$

$$F_{net} = 8 + 10 + (-25) + (-12)$$

$$F_{net} = -19\ N$$

$$F_{net} = 19\ N\ left$$

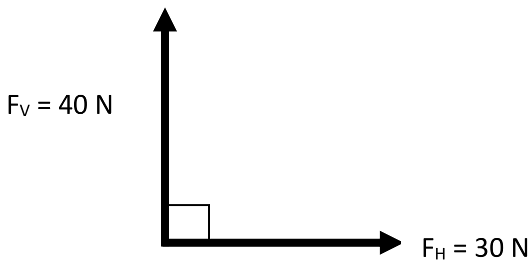


Vectors in Two Dimension

Resultant of perpendicular vectors

- **Perpendicular vectors** are at right angles to each other.
- A horizontal force of 30 N and a vertical force of 40 N that act on an object are an example of two forces that are perpendicular to each other.

Diagram



Adding co-linear vectors

- Vectors that act in one dimension are called co-linear vectors
- The net x-component (R_x) is the sum of the vectors parallel with the x-direction: $R_x = R_{x1} + R_{x2}$
- The net y-component (R_y) is the sum of the vectors perpendicular to the x-direction: $R_y = R_{y1} + R_{y2}$

Worked Example

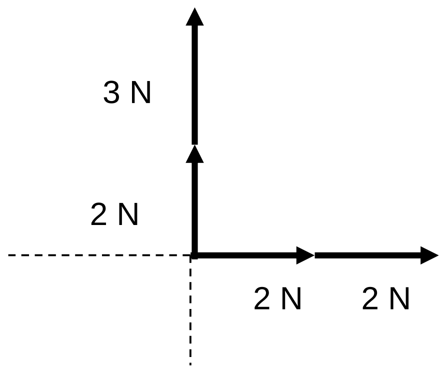
Two forces of 3N and 2N apply an upward force to an object. At the same time two forces each of 2N act horizontally to the right. Find the resultant force acting on the object.

Step 1: Draw a diagram and calculate the net vertical and net horizontal forces

$R_y = R_{y1} + R_{y2}$

$R_y = 2 + 3$

$R_y = 5\ N\ upwards$

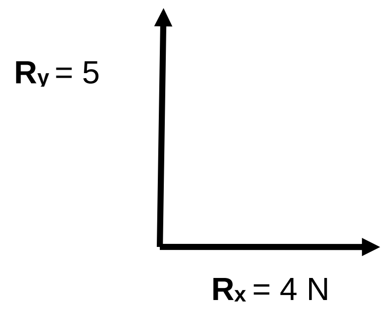


$R_x = R_{x1} + R_{x2}$

$R_x = 2 + 2$

$R_x = 4\ N\ right$

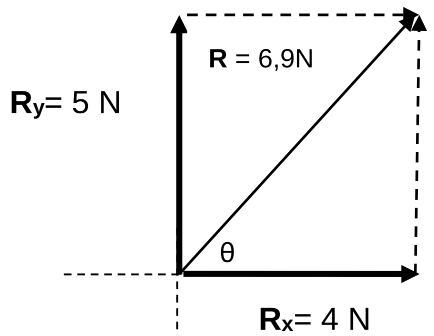
Step 2: Graphical representation of R_x and R_y



Step 3: To find resultant (R) of the above vectors, one can using **tail-to-tail** drawing of vectors

Tail to tail method or Parallelogram:

Note: When vectors are drawn tail-to-tail, a parallelogram must be completed in order to determine their resultant.



- Phythagoras theorem is used to calculate the magnitude of the resultant.
- Considering the vector diagram above we can use Pythagoras theorem as follows:

$$R^2 = {R_x}^2 + {R_y}^2$$
$$R^2 = 4^2 + 5^2$$
$$R = \sqrt{4^2 + 5^2}$$
$$R = 6.40\ N$$

- Use trigonometry to find the direction of the resultant as follows:

$$\tan\theta = \frac{R_y}{R_x} = \frac{5}{4}$$

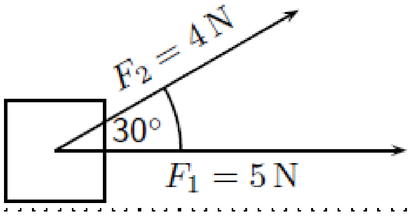
$$\therefore\ \theta = 51{,}34°$$

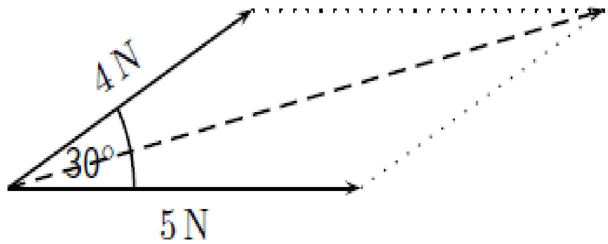
Worked Example:

A force of F_1 = 5N is applied to a block in a horizontal direction. A second force F_2 = 4N is applied to the object at an angle of 30º above the horizontal. Determine the resultant of the two forces**, by accurate scale drawing.**

Step 1: Draw rough sketches of the vector diagrams:

Note: Forces are NOT perpendicular





Step 2: Choose the suitable scale. e.g 1cm : 1N

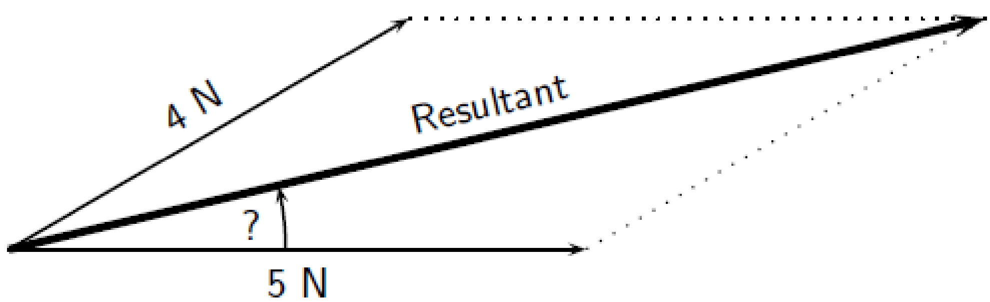
Step 3: Draw the first vector (F_1) on the horizontal, according to the scale.

Step 4: Draw the second scaled vector (F_2) 30º above the horizontal.

Step 5: Complete the parallelogram and draw the diagonal (which is the resultant)

Step 6: Use the protractor to measure the angle between the horizontal and the resultant.

Step 7: Apply scale and convert the measured length to the actual magnitude.



The resultant is 8,7N, 13,3º above the horizontal.

GRAPHICAL DETERMINATION OF THE RESULTANT VECTOR

Tail-to-head method is used to find the resultant of two or more consecutive vectors (vectors that are successive)

Steps to be followed:

- Choose the suitable scale e.g. 10mm : 10N
- Accurately draw the first vector as an arrow according to chosen scale and in the correct direction
- Draw the second vector by placing the tail of the second vector at the tip of the first vector { tail – to – head method}
- Complete the diagram by drawing the resultant from the tail of the first vector to the head of the last vector.
- Make sure that you measure the angles correctly with a protractor.
- Always add arrow heads to vectors to indicate the direction.
- Measure the length and direction of the resultant vector.

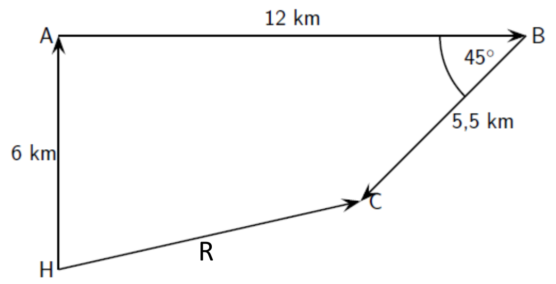
Use the scale to determine the real magnitude of the resultant.

Worked Example 1:

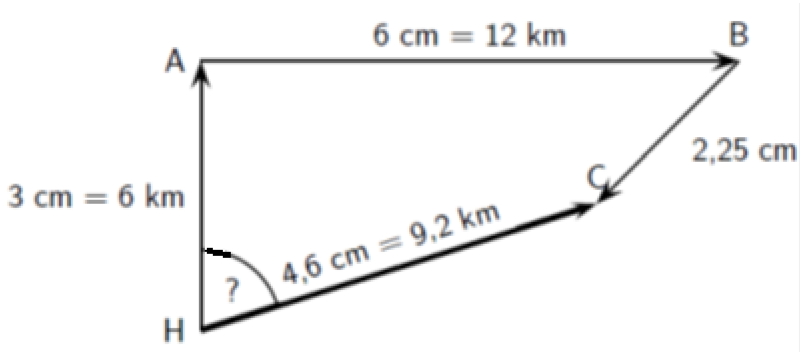
A ship leaves a harbour H and sails 6km north to port A. From here the ship travels 12 km east to port B, before sailing 5,5 km at 45^0 south-west to port C.

Determine the ship's restaurant displacement using the tail-to-head technique.

Rough sketch:



Using a scale 1cm : 2km, the accurate drawing of vectors is:



Measure the angle between the North line and the resultant with a protractor to find that the direction of the resultant displacement:

Resultant displacement of the ship is 9,2 km on a bearing of 72, 3º.

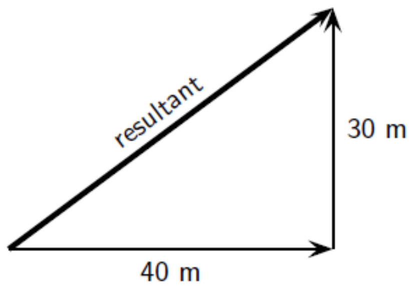
Example 2:

A man walks 40m East, then 30m North. Use a scale of 1 cm: 10 m and answer the following questions:

1. What was the total distance he walked?
2. Determine by construction his resultant displacement?
3. Calculate determine the direction of the resultant.
4. Calculate the magnitude of resultant displacement

Solutions:

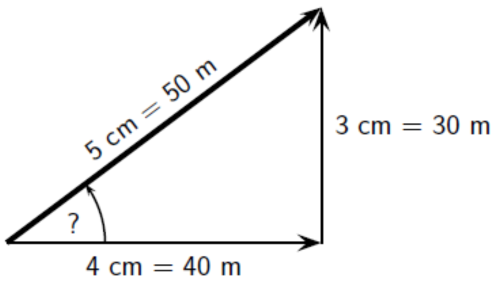
1. Rough sketch



Total distance = 40m + 30m

= 70m

2. Scale: 1cm : 10m



The resultant is 50m, 37º from the horizontal

3. $\tan \Phi = \frac{30}{40}$

   $\Phi = 36{,}87^{\circ}$

4. $R^2 = x^2 + y^2$

   $= 40^2 + 30^2$

   $= 2500$

   $R = 50m$

THE TRIANGLE RULE FOR FORCES IN EQUILIBRIUM

Closed vector diagram

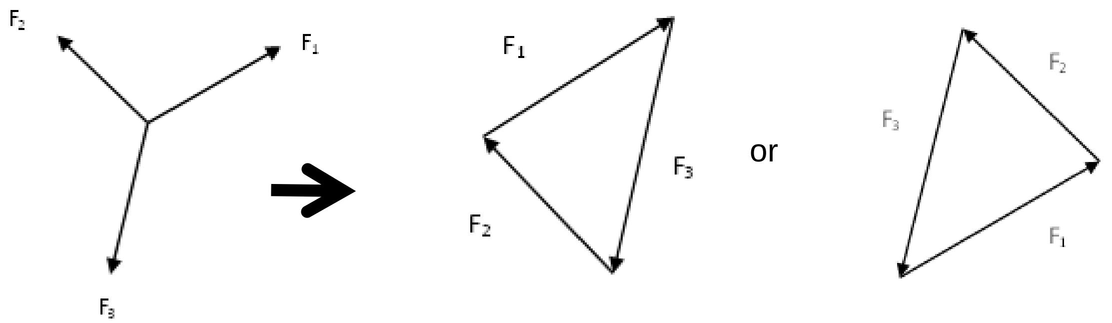
- When drawing force vectors **at equilibrium**, a closed quadrilateral such as triangle (closed vector diagram) will be obtained. In that case, **the resultant is zero and all vectors are drawn from head-to-tail.**
- The forces F_1, $F_2$and F_3 act on the same object and keep it in equilibrium so that the object does not move, or continues moving with the constant velocity. (No change in motion occurs).
- These three forces can be shifted to form a close triangle, where the sides of the triangle still represent the magnitude and direction of the forces.

The triangle rule for forces in equilibrium is as follows:

When three forces acting at the point are in equilibrium, they can be represented in both magnitude and direction by the three sides of a triangle taken in order.

- The triangle is formed because the three forces are in equilibrium.
  $F_1+F_2+F_3=0$

For example: when the forces F_1, F_2 and F_3 are in equilibrium, they can be represented by a closed triangle as:

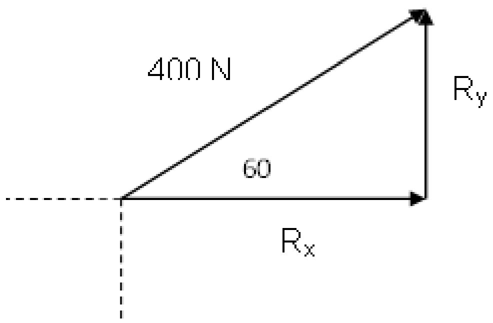


RESOLUTION OF A VECTOR INTO ITS PARALLEL AND PERPENDICULAR COMPONENTS

- The process of breaking down the vector quantity into its components that are at right angles to each other is known as ***resolving a vector*** into its components.

Worked Example

A force of 400N acts at an angle 60^0 to the horizontal.



Horizontal component:

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\cos 60^o = \frac{R_x}{400\text{ N}}$$

$$R_x = 400\text{N} \cdot \cos 60^o$$

$$R_x = 200\text{N}$$

Vertical component:

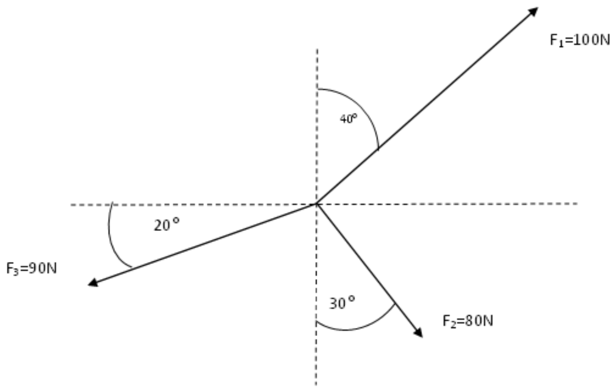
$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\sin 60^o = \frac{R_y}{400\text{ N}}$$

$$R_y = 400\text{N} \cdot \sin 60^o$$

$$R_y = 346{,}41\text{N}$$

Finding resultant of vectors acting at angles (using component method)



Step 1: Find horizontal and vertical components of each force.

Components of F_1:

Horizontal (F_x)

$(F_x) = F_1 \sin\Phi$

$= 100 \sin 40^o$

$= 64,28$N (right)

Vertical (F_y)

$(F_y) = F_1 \cos\Phi$

$= 100 \cos 40^o$

$= 76,60$N (up)

Components of F_2:

Horizontal (F_x)

$(F_x) = F_2 \sin\Phi$

$= 80 \sin 30^o$

$= 40$N (right)

Vertical (F_y)

$(F_y) = F_2 \cos\Phi$

$= 80 \cos 30^o$

$= 69,28$N (down)

Components of F_3:

Horizontal (F_x)

$(F_x) = F_3 \cos\Phi$

$= 90 \cos 20^o$

$= 84,57$N (left)

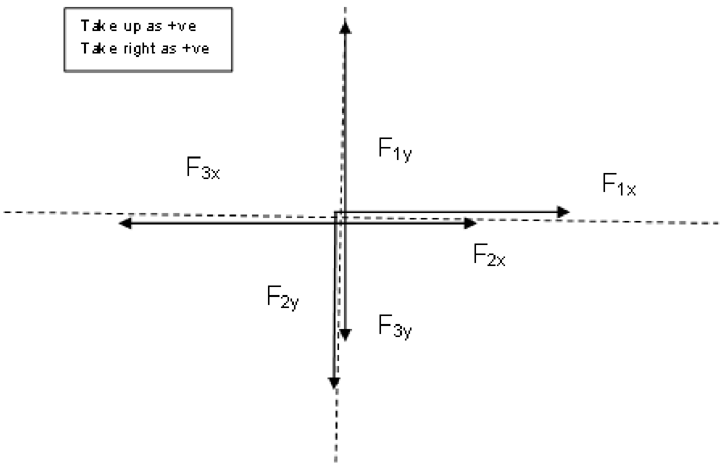
Vertical (F_y)

$(F_y) = F_3 \sin\Phi$

$= 90 \sin 20^o$

$= 30,78$N (down)

Step 2: Hence, the new situation is:



Step 3:

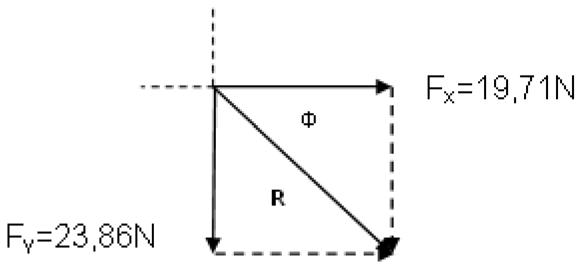
Thus, the sum of horizontal components = 64,28+40+ (-84,57)

= 19,71N to the right

And the sum of vertical components = 69,28+30,78+ (-76,20)

= 23,46N downwards

Step 4:



The resultant of the two vectors (at right angles to each other) is:

$\mathbf{R}^2 = R_x^2 + R_y^2$

$= 19{,}71^2+23{,}86^2$

$= 30{,}64N$

$\tan \Phi = 23{,}86/19{,}71$

$\Phi = 50{,}47^o$

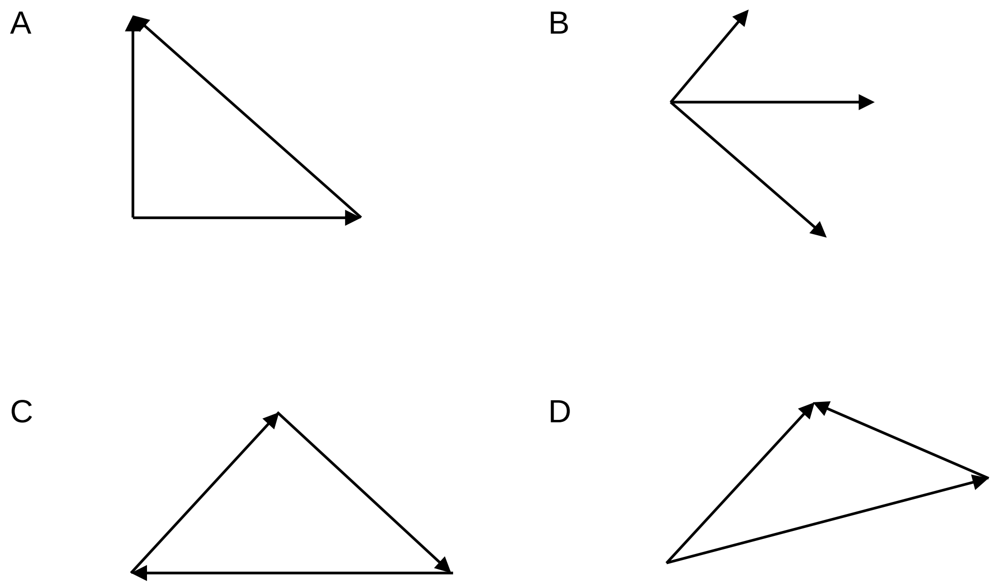
Thus, the resultant of the three forces is 30,95N in a bearing of 50,47º from the horizontal.

Exam questions

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 D.

1.1 Consider the following vector diagrams. Which ONE of these vector diagrams represents a zero resultant?



(2)

1.2 If the resultant of two forces acting at a point is zero, the forces …

A are of equal magnitude and act perpendicular to each other.

B are of different magnitudes, but act in opposite directions.

C are of equal magnitude and act in the same direction.

D are of equal magnitude, but act in opposite directions. (2)

1.3 Two forces of magnitudes 3 N and 4 N respectively act on a body. The maximum magnitude of the resultant of these forces is …

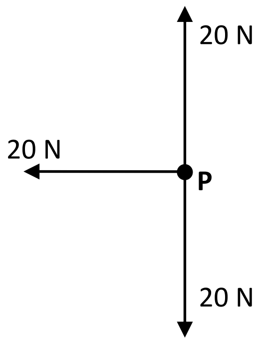
A 12 N.

B 7 N.

C 5 N.

D 1 N. (2)

1.4 Three forces of magnitude 20 N each act on object **P** as shown below.



The resultant force on object **P** is …

A zero.

B 20 N to the left.

C 20 N upwards.

D 20 N downwards. (2)

1.5 Two forces of magnitudes 15 N and 20 N act at a point on an object. Which one of the following magnitudes CANNOT be the resultant of these forces?

A. 35 N

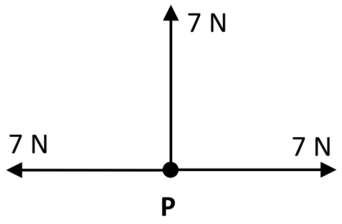
B. 10 N

C. 4 N

D. 18 N

(2)

1.6 Three forces, each of magnitude 7 N, act on object **P** as shown.



The resultant force on object **P** is …

A zero.

B 7 N to the left.

C 7 N upwards.

D 7 N downwards. (2)

1.7 Two forces of magnitude 50 N and 70 N respectively act on a body. The maximum magnitude of the resultant force on the body is ...

A 20 N.

B 60 N.

C 120 N.

D 140 N. (2)

1.8 Two forces of magnitudes 8 N and 6 N are added to each other. Which of the following values CANNOT be a resultant of these two forces?

A 2 N

B 3 N

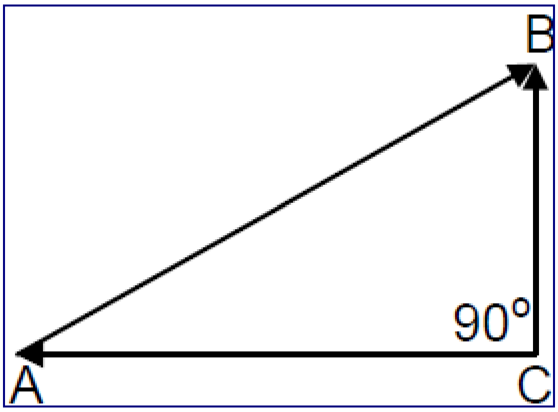
C 14 N

D 16 N (2)

1.9 You can replace two forces, P and Q, with a single force of 7 N. If the magnitude of force P is 3 N, which one of the following can be the magnitude of force Q?

A 2 N
B 3 N
C 8 N
D 13N (2)

1.10 Consider the following vector diagram:



The vector which represents the resultant of the other two, is …

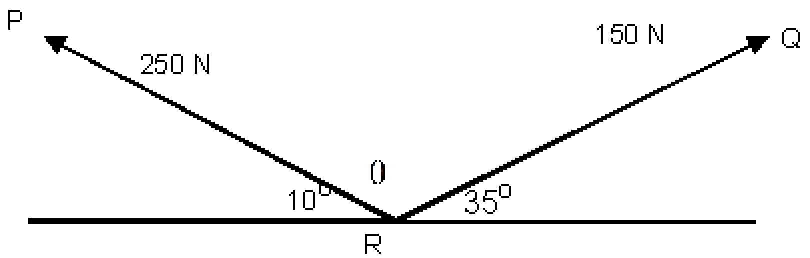
A. AB.
B. AC.
C. CB.
D. BA.

(2)

STRUCTURED QUESTION

QUESTION 1 (Grade11 KZN MARCH 2015)

The diagram below shows TWO forces **P** and **Q** of magnitude 250 N and 150 N respectively acting at a point **R**.



1.1 Calculate the horizontal and vertical components of vector P. (4)

1.2 Calculate the vector sum of horizontal components of P and Q. (3)

1.3 The vector sum of the vertical components of these forces is 129,45 N.

Using the vector sums of the horizontal and vertical components of P and Q, draw a labeled force vector diagram to show the resultant force acting on the point R. (3)

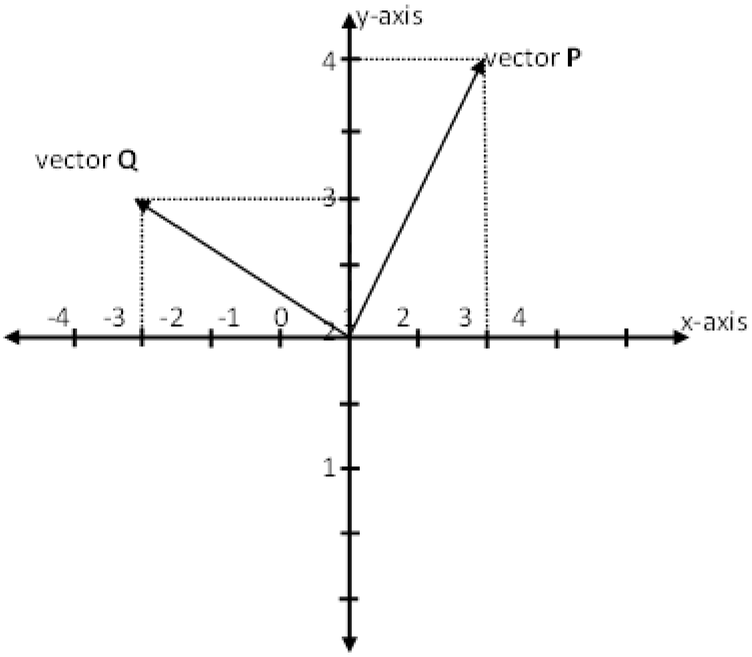
1.4 Calculate the magnitude of the resultant of forces P and Q. (3)

1.5 Calculate the direction (measured clockwise from the positive Y axis) of the resultant of vectors P and Q. (3)

1.6 If vector P was fixed but the direction of vector Q could be changed, for which value of Ɵ will the resultant force have a maximum value? (1)

QUESTION 2 (FS CONTROL TEST TERM 1 – 2014)

Force vectors **P** and **Q** were drawn to scale on the Cartesian plane shown below.



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

2.2. From the graph, without using a scale drawing, CALCULATE the (no units are required):

2.2.1 Magnitude of the horizontal component of vector **P** (1)

2.2.2 Magnitude of the horizontal component of the resultant of vectors **P** and **Q** (2)

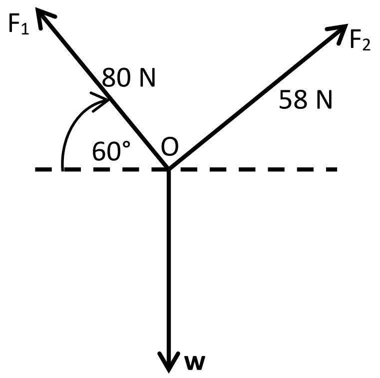
2.2.3 Magnitude of the vertical component of the resultant of vector **P** and **Q** (2)

2.2.4 Resultant of vectors **P** and **Q**. (6)

[13]

QUESTION 3(Fs CONTROL TEST TERM 1 – 2015)

Three forces, $\mathbf{F_1}$, $\mathbf{F_2}$ and **w**, act on point **O** as shown in the diagram below.



3.1 Define the term *resultant of forces*. (2)

3.2 By means of an accurate scale drawing, determine the vertical component of $\mathbf{F_1}$. Use a scale where 10 N is represented by 10 mm. (5)

3.3 The horizontal and vertical components of $\mathbf{F_2}$ are equal to 40 N and 42 N respectively.

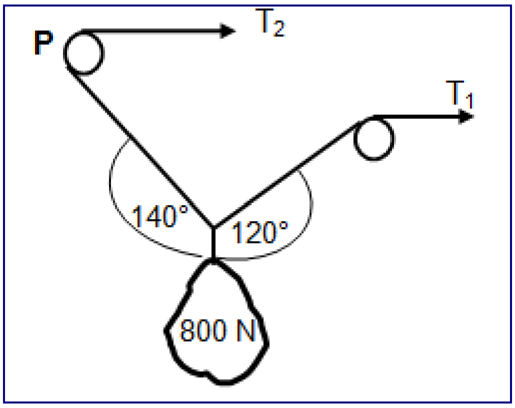
3.3.1 Prove with calculations that the horizontal components of the forces are in equilibrium. (3)

3.3.2 Calculate the magnitude and direction of force **w**. (2)

[12]

QUESTION 4

The diagram below shows a rope and pulley arrangement of a device being used to lift an 800 N object. Assume that the ropes are light and inextensible and also that the pulley is light and frictionless.



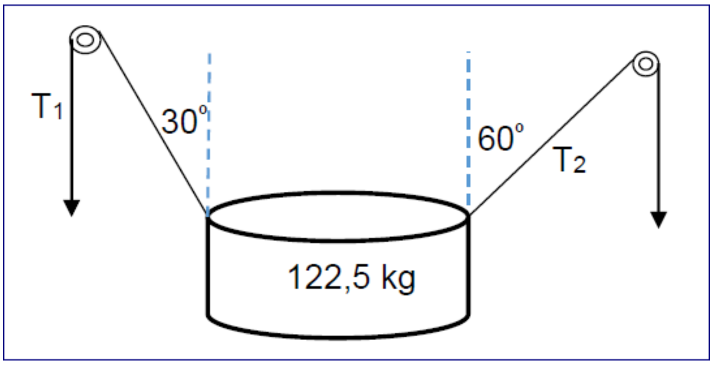
Deter mine the:

2.1 Magnitudes of the tensions $\mathbf{T_1}$ and $\mathbf{T_2}$ (7)

2.2 Magnitude and direction of the reaction force at pulley **P** (4)

QUESTION 5 (EC NOV 2016)

The diagram below shows a rope and pulley system of a device being used to lift a 122,5 kg container upwards at a constant velocity. Assume that the ropes are light and inextensible and the pulley is frictionless.



5.1 Calculate the weight of the container. (3)

5.2 The system is moving upwards at a constant velocity as indicated above.

5.2.1 Draw a vector diagram of all forces acting on the container and indicate the angles represented in the diagram. (5)

5.2.2 Determine the magnitudes of the forces **T1** and **T2**. (7)

5.3 The system is moving upwards at a constant velocity.

5.3.1 What does the statement above tell us about forces acting on the container? (2)

5.3.2 Which Newton's law support your answer in QUESTION 5.3.1? (2)

Solutions to Vectors activities

QUESTION 1: MULTIPLE-CHOICE

1.1	C ✓✓	(2)
1.2	D ✓✓	(2)
1.3	B ✓✓	(2)
1.4	B ✓✓	(2)
1.5	C✓✓	(2)
1.6	C ✓✓	(2)
1.7	C ✓✓	(2)
1.8	D ✓✓	(2)
1.9	D ✓✓	(2)
1.10	B✓✓	(2)

STRUCTURED QUESTION

QUESTION 1:

1.1 $F_{PX} = F_P \cdot \cos\Theta$

$= 250 \times \cos 10^0$ ✓

$= 246{,}20$ N ✓

$F_{PY} = FP \cdot \sin\Theta$

$= 250 \times \sin 10^0$ ✓

$= 43{,}41$ N ✓ (4)

1.2 $F_{QX} = F \cos\Theta$

$= 150 \cos 35^0$

$= 122{,}87$ N to the right ✓

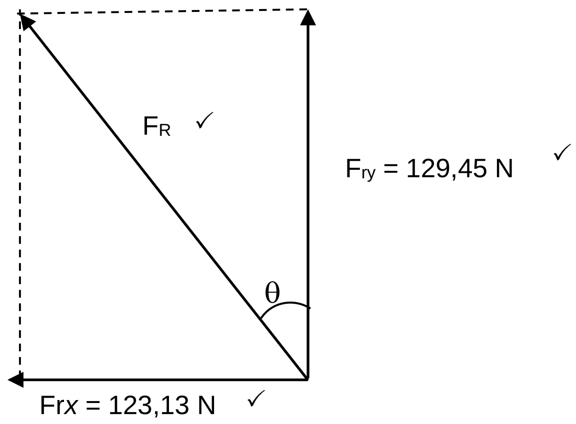
$F_{Rx} = F_{Xp} + F_{XQ}$

$= -246 + 122{,}87$ ✓

$= -123{,}13$N

$= 123{,}13$ N to the left✓ (3)

1.3



(3)

1.4 $F_R{}^2 = F_{Rx}{}^2 + F_{Ry}{}^2$ ✓

$F_R{}^2 = (123,13)^2 + (129,45)^2$ ✓

$F_R{}^2 = 15161 + 16757,30$

$F_R{}^2 = 31918,30$

$F_R = 178,66$ N ✓ (3)

1.5 $\tan\theta = F_{Rx} / F_{Ry}$

$\theta = 123,13/ 129,45 \tan^{-1}$ ✓

$\theta = 43,57^0$ ✓

Direction = $360^o - 43,57^o = 316,43^o$ ✓ (3)

1.6 0^o ✓ (1)

[17]

QUESTION 2 *(FS 2014)*

2.1. The vector with same effect ✓ as all the vectors together. ✓ (2)

2.2.1 2 ✓ (1)

2.2.2 $R_H = P_H + Q_H = 2 + (-3)$✓ $= -1$✓ (2)

2.2.3 $R_V = P_V + Q_V = 4 + 2$✓ $= 6$ ✓ (2)

2.2.4 $R^2 = R_H{}^2 + R_V{}^2 = (-1^2) + 6^2$ ✓$= 37$

$\therefore R = 6,08$ ✓

$\tan\theta = \frac{R_H}{R_V} = \frac{-1}{6}$ ✓ $= -0{,}17$ $\therefore\theta$ = -9,65°

Φ = 360° - 9,65° ✓= 350,35°✓

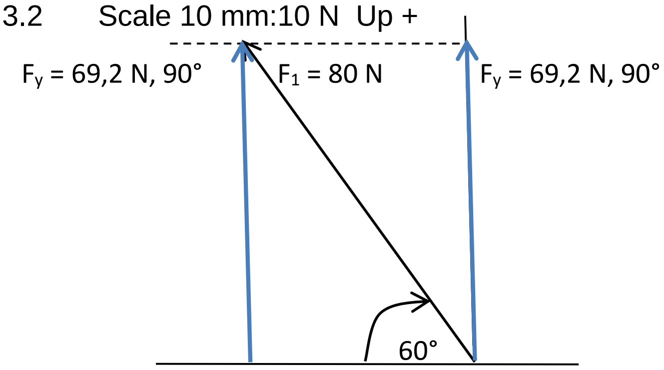
Resultant = <u>6,08 N; 350,35°</u> ✓ (6)

[13]

QUESTION 3 (FS 2015)

3.1. The vector with same effect ✓ as all the vectors together. ✓ (2)

3.2 Scale 10 mm:10 N Up +



Direction of F_1 60° above x-axis	✓
Length of F_1 80 mm	✓
Lines prependicular to the x- or y-axis from arrowhead of F_1	✓
Length of F_y between 66 mm < F_y < 72 mm	✓
F_y between 66 N, 90° < F_y < 72 N, 90°	✓

(5)

3.3.1 To the right as positive:

F_{xNET} = $F_{1x} + F_{2x}$
= F_1 x cos 60°+ F_{2x}
= - 80 x 0,5 ✓ + 40 ✓
= - 40 + 40
= 0 □ (3)

3.3.2 **POSITIVE MARKING FROM QUESTION 3.2.**

w = $F_{1y} + F_{2y}$
w = 69, 2 + (42) ✓
∴w = 111, 2 N; downwards (2)

Newton’s Law’s and Application of Newton’s Laws

Different kinds of forces:

Normal force (N) is the force or the component of a force exerted by the surface on an object in contact with.

Normal force is always perpendicular to the surface irrespective of whether the plane is horizontal or inclined.

Frictional force is the force that opposes the motion of an object and acts parallel to the surface the object is in contact with.

Know that a frictional force is proportional to normal force and independent to area of the surface that are in contact with each other

Static friction is the force that opposes the tendency of motion of a stationary object relative to the surface.

Maximum static friction is the force which can overcome static friction and just cause an object to slide.

Kinetic friction is the force that opposes the motion of a moving object relative to the surface.

Gravitational force or weight ("$_g$ or w) is a force with which the earth attract an object towards itself.

Applied forces (push or pull)

Tension ("F_T or ") is the force that is transmitted through a rope, string or wire when pulled by forces acting from opposite sides.

Objects exert push (repulsion) or pull (attraction) forces on each other.

A force can be classified as either a *contact force* or a *non-contact force*

Objects can exert a force on each other when they are in contact (touching each other) e.g. friction and normal forces

OR

Objects can exert a force on each other when they are not in contact (i.e. are apart from each other) e.g. magnetic, electrostatic and gravitational forces.

The following equations are used to calculate maximum static friction (f_s^{max}) and kinetic friction:

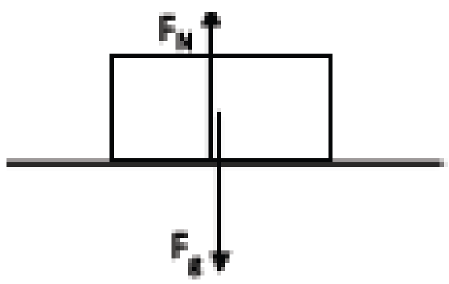
$$f_s^{max} = \mu_s N$$

$$f_k = \mu_k N$$

- μ_s is coefficient of static friction
- μ_k is coefficient of kinetic friction
- μ_s and μ_k have no units

for an object to move, $f_k › f_s$

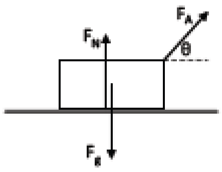
QUANTITY NAME	QUANTITY SYMBOL	UNIT NAME	UNIT SYMBOL
Maximum static friction	f_s^{max}	Newton	N
Normal force	N	Newton	N
Kinetic friction	f_k	Newtons	N
Net force	F_{net}	Newton	N
Mass	m	kilogram	Kg
Acceleration	a	metres per second squared	$m \cdot s^{-2}$

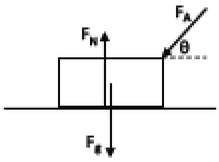


$F_N = mg$

$F_k = \mu_k N$

$F_k = \mu_k mg$





For a pulling force:

$F_N + F_Y = W$

$F_N = W - F_Y$

$F_k = \mu_k N$

$F_k = \mu_k (W - F_Y)$

$= \mu_k(mg – F_a \sin θ)$

For a pushing force:

$F_N - F_Y = W$

$F_N = W + F_Y$

$F_k = \mu_k N$

$F_k = \mu_k (W + F_Y)$

$= \mu_k(mg + F_a \sin θ)$

EFFECT OF A CHANGING ANGLE

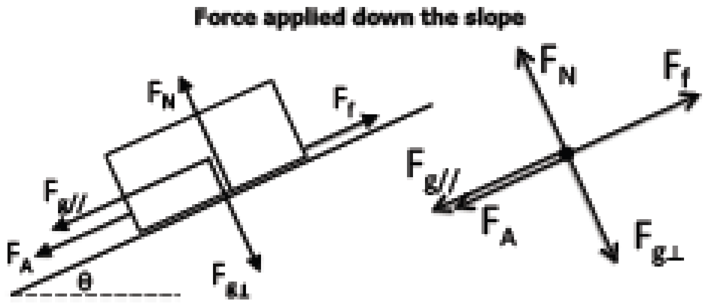
For a pulling force:

- 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.

For a pushing force:

- 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.

  NB: Any change made on an angle will affect the co-efficient of kinetic friction (μ_k)



$F_N = F_{g⊥}$

$F_N = mg \cos θ$

$F_k = \mu_k N$

$= \mu_k (mg \cos θ)$

EFFECT OF A CHANGING ANGLE

- 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.

Force diagrams and free body diagrams

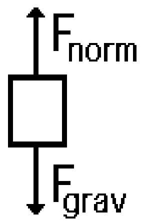
A force diagram is a picture of the object(s) of interest with all the forces acting on it (them) drawn in as arrows

How to draw a force diagram

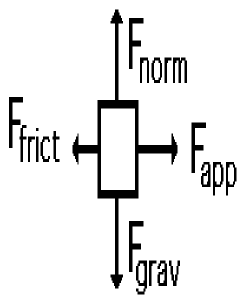
- draw a picture of the object
- draw all arrows from the object outwards(the length of the arrow indicate the magnitude of the force)

Examples:

1. A book is at rest on a tabletop. A force diagram for this situation looks like this:



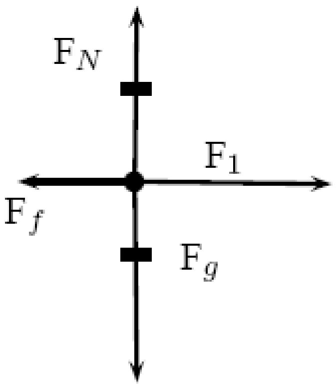
2. A force is applied to the right to drag a crate across the floor with a rightward acceleration. A force diagram for this situation looks like this:



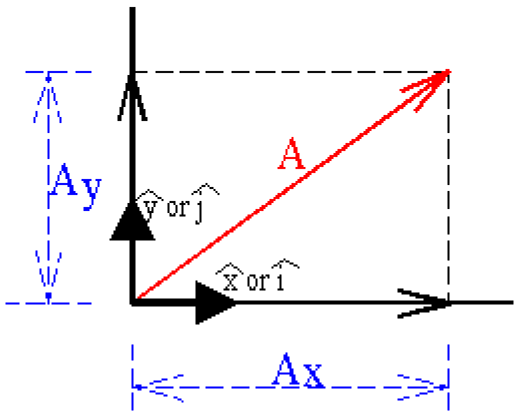
A free body diagram is a picture of an object of interest drawn as a dot and all the forces acting on it are drawn as arrows pointing away from the dot **(in a free body diagram the object is represented by a dot)**

Example

Step 1: A force is applied to the right to drag a crate across the floor with a rightward acceleration. A free body diagram for this situation looks like this:



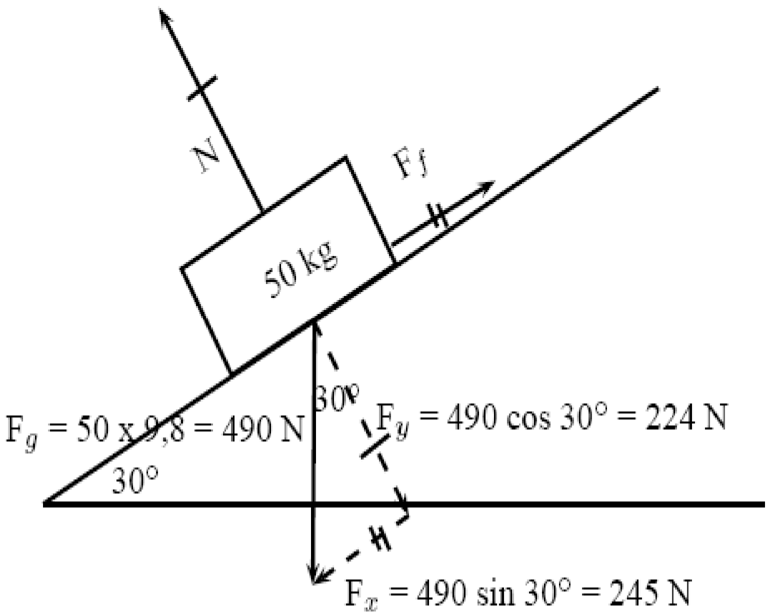
Step 2: The resultant or net force in the x-direction is a vector sum of all the components in the x-direction and the resultant or net force in the y-direction is a vector sum of all the components in the y-direction.



- **A_X** in the above diagram is resultant or net force in the x-direction.
- **A_Y** in the above diagram is resultant or net force in the y-direction.

Resolving weight into its components

The following is a force diagram for a box of mass 50 kg at rest on an inclined plane. The weight has been resolved to its x component (parallel to the plane) and y components (vertical to the plane).



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 acts on it.

- **Inertia** is the resistance of an object to any change in its state of motion. The mass of an object is a quantitative measure of its inertia.

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 $km.h^{-1}$ (33.33$m.s^{-1}$), the passengers in the car are also travelling at 120 $km.h^{-1}$.(33.33$m.s^{-1}$)
- 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 – according 120 $km.h^{-1}$ (33.33$m.s^{-1}$) to Newton first law.
- If they are wearing seat belts, the seat belts will stop them and therefore prevent them from getting hurt.

Newton's second law

When a net force is applied to an object of a certain mass, the object accelerates in the direction of the net force. The acceleration is directly proportional to the net force and inversely proportional to the mass.

Unit conversion:

1000g = 1kg

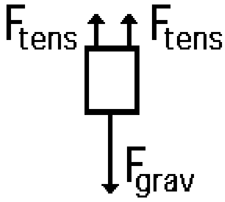
Examples

1. Determine the acceleration that result when a 12N net force is applied to a 3kg object.

$$F_{net} = ma$$
$$12 = 3a$$
$$a = 4\ m\cdot s^{-2} \text{ in the direction of the force}$$

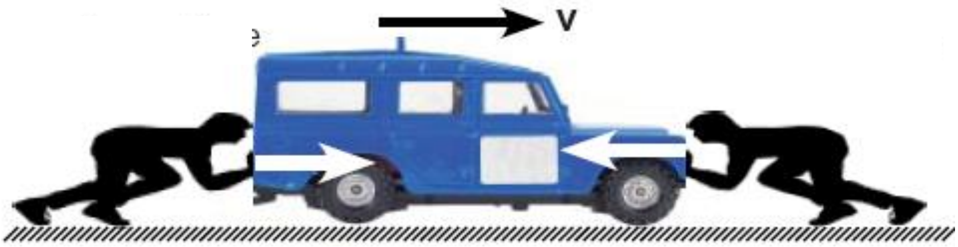
Examples of objects in equilibrium:

1. A girl is suspended **motionless** from the ceiling by two ropes. A force diagram for this situation looks like this:

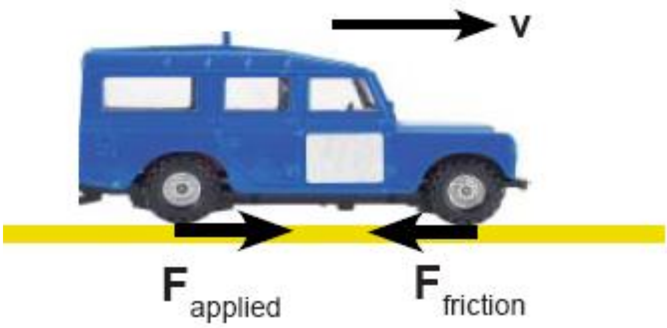


2.

a)



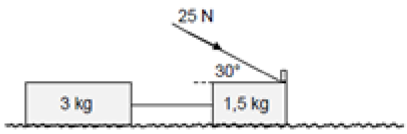
b)



- In the above diagrams there is no change in velocity. Thus no acceleration. **We call this equilibrium.**
- The forces applied on the same object are equal in magnitude but acts in opposite direction.
- At **constant velocity,** the acceleration is equal to zero, therefore $F_{net} = 0$, since the forces acting on an object are balanced.

EXAMPLE 2

A learner constructs a push toy using two blocks with masses 1,5kg and 3kg respectively. The blocks are connected by mass-less, inextensible cord.
The learners then applies the force 25N at an angle 30º to the 1,5kg 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 co-efficient 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)

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

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

$$F_k = \mu_k N$$

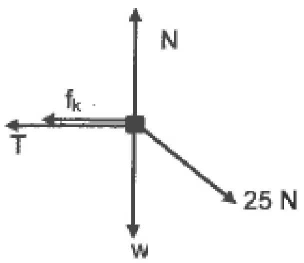
$$F_k = \mu_k mg$$

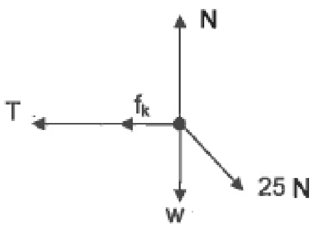
$$F_k = (0{,}15)(3)(9{,}8)$$

$$F_k = 4{,}41\ N$$

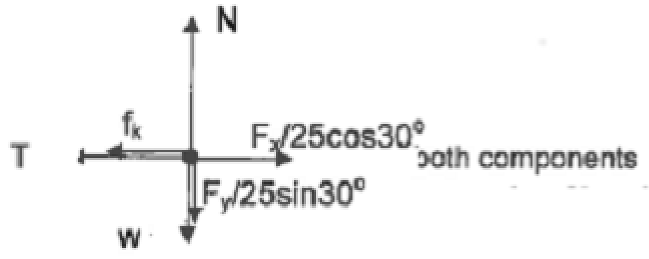
2.3 Draw a labelled free-body diagram 5

Without showing components of weight





Showing components of weight



2.4 Calculate the magnitude of the :

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

Option 1

$F_k = \mu_k N$

$F_k = \mu_k\,(25\sin 30^o + mg)$

$F_k = (0{,}15)[(25\sin 30^o) + (1{,}5)(9{,}8)]$

$F_k = 4{,}08\ N$

Option 2

$F_k = \mu_k N$

$F_k = \mu_k\,(25\cos 60^o + mg)$

$F_k = (0{,}15)[(25\cos 60^o) + (1{,}5)(9{,}8)]$

$F_k = 4{,}08\ N$

2.4.2 Tension in the cord connecting the two blocks 5

For the 1,5 kg block

$F_{net} = ma$

$F_x + (-T) + (-f_k) = ma$

$(25\cos 30^o) - T - 4{,}08 \ = (1{,}5)a]$

17,571- T = 1,5a.................(1)

For the 3kg block

T – f_k = 3a

T- 4,41 = 3a...................(2)

(1) +(2)

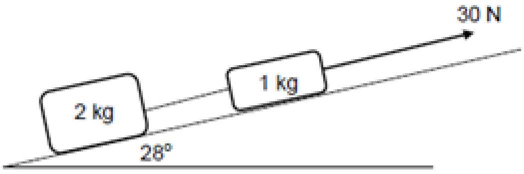
13.161= 4,5a

a= 2,925m·s^{-2}

T = 13,19N

EXAMPLE 3

In the diagram below, a 2kg block is connected to a 1kg block by means of alight inextensible string. The blocks are pulled up an inclined plane, which form an angle of 28º to the horizontal. The sides of the blocks which touch

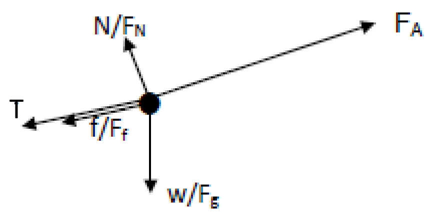


The kinetic frictional force between the 1kg block and the inclined plane is 4N while the kinetic frictional force between the 2kg block and the inclined plane is 8N.

3.1.1 Draw a labelled free-body diagram sowing ALL forces acting on the 1kg block. 5

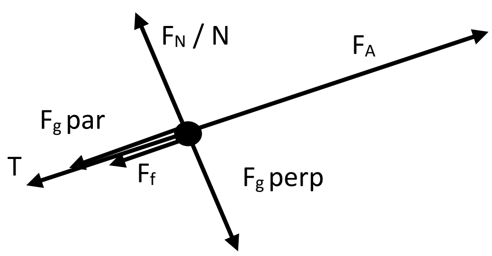
Free-body diagram:

Option 1 (without components)



Note:
- Use a dot
- Lines must touch the dot
- All lines must have arrows
- Do not show components together with the force

Option 2 (with components of weight)



F_g par = component of weight parallel to slope

F_g perp = component of weight perpendicular to slope

3.1.2 Calculate the tension on the string connecting the blocks 5

F_{net} =ma

30-(T+ mg Sin 28º + f_k) = ma

30- (T+(1)(9,9)(Sin28º) +4) = (1)a

21,399 – T = a……………………(1)

For the 2kg block

F_{net} =m

T-{(2)(9.8)(Sin28º)+4)}=2(a)

T-17,201=2a……………..(2)

Substitute for T from equation (1)

(21,399-a)-17,2011 = 3a

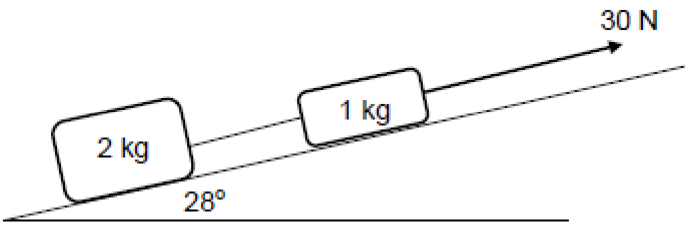
a=1,4m·s^{-2}

Substitute $a=1,4 m•s^{-2}$ in (1)

21,399 –T= (1,4)

T= 20N

3.1 In the diagram below, a 2 kg block is connected to a 1 kg block by means of a light inextensible string. The blocks are pulled up an inclined plane, which forms an angle of 28º to the horizontal. The sides of the blocks which touch the inclined plane have the same area.

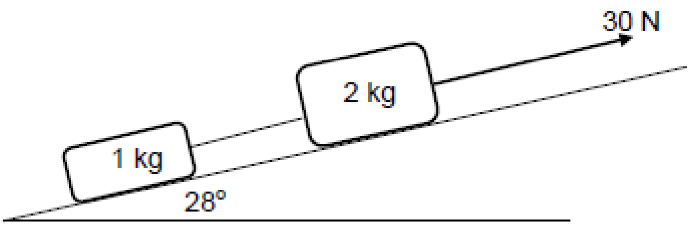


The kinetic frictional force between the 1 kg block and the inclined plane is 4 N while the frictional force between the 2 kg block and the inclined plane is 8 N

3.1.1 Draw a labelled free-body diagram showing All forces acting on the 1 kg block (5)

3.1.2. Calculate the magnitude of the tension in the string connecting the blocks. (5)

Ans. The two blocks are interchanged so that the SAME 30 N force is now acting on the 2 kg block along the inclined plane, as shown in the diagram below.



$$F_{net} = ma$$
$$30 - (T + mg \sin 28^o + f_k) = ma$$
$$30 - (T + (1)(9,8)(\sin 28^o) + 4) = (1)a$$
$$21,399 - T = a \ldots\ldots\ldots\ldots\ldots..(1)$$

For the 2 kg block

$F_{net} = ma$ $T - (mgSin\ 28^o + f_k) = ma$ $T - [((2)(9,8)(\sin 28^o) + 8)] = (2)a$ $T - 17,201 = 2a \ldots\ldots\ldots\ldots\ldots (2)$	$21,399 - T = a \ldots\ldots\ldots\ldots\ldots (1)$ $T - 17,201 = 2a \ldots\ldots\ldots\ldots (2)$ $T - 17,201 = 2(21,399 - T)$ $T = 20\ N$
Substitute for T from equation (1)	
$(21,399 - a) - 17,201 = 3a$ $4,198 = 3a$ $a = 1,4\ m \cdot s^{-2}$	
From (1)	From (2)
$T = 21,399 - a$ $T = 21,399 - 1,399$ $T = 20\ N$	$T = 17,201 + 2(1,399)$ $T = 20\ N$

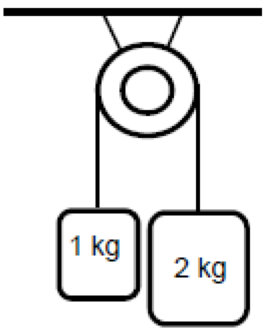
3.1.3 How will the acceleration of the system change? Write down only INCREASE, DECREASE or REMAIN THE SAME (1)

Remain the same

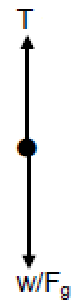
3.1.4 How will the acceleration of the system change? Write down only INCREASE, DECREASE or REMAIN THE SAME (1)

Remain the same

3.2. In the diagram below, a 1 kg mass and a 2 kg mass are connected by an inextensible string of negligible mass. The string is passed over a light frictionless pulley so that the masses hang down as shown. Initially the system is held stationary



3.2.1 Draw a labelled free-body diagram showing ALL the forces acting on the 2 kg mass. (2)



3.2.2 Calculate the time it will take the 1 kg mass to move a distance of 1 m when the system is released. (7)

SOLUTIONS

3.1.3 Remains the same **1**

3.1.4 Remains the same **1**

3.2.1 **2**

3.2.2 **7**

OPTION 1

$F_{net} = ma$

For the 1 kg block

$T – (1)(9,8) = (1)a$

$\therefore T – 9,8 = a$......... ..(1)

1 mark for any of the 2

For the 2 kg block

$(2)(9,8) – T = 2a$

$\therefore$ $19,6 – T = 2a$......... (2)

1 mark for any of the 2

From (1) and (2)

$9,8 = 3a$

$\therefore$ $a = 3,27 \text{ m·s}^{-2}$

$\Delta y = v_i\Delta t + ½ a\Delta t^2$

$-1 = 0 + ½ (-3,27)\Delta t^2$

$\Delta t = 0,78 \text{ s}$

OR/*OF*

$\Delta y = v_i\Delta t + ½ a\Delta t^2$

$1 = 0 + ½ (3,27)\Delta t^2$

$\Delta t = 0,78 \text{ s}$

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. (The forces are therefore an interaction between two bodies.)

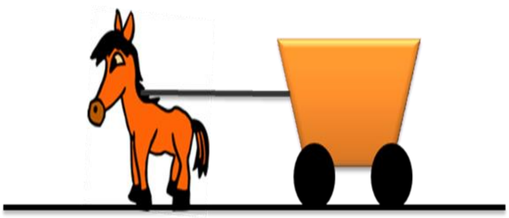
Identification of action-reaction pairs:

Scenario 1:
You are given a vase resting on a table, as shown below.

(a) Identify all the action–reaction forces for the vase.
(b) Identify all the action–reaction forces for the table.

Note:
A vase on the table exerts a force, (W = mg) on the table downwards, and the table exerts equal but upwards force on the vase. It is important to note that ***whilst the two forces are equal in magnitude and opposite in direction, they cannot cancel*** since **they do not act on the same object.**

Scenario 2:



A donkey is pulling a cart along a road (as shown above). We know from Newton's third law that the force exerted by the donkey on the cart is equal and opposite to the force exerted by the cart on the donkey.

Which force/forces cause the motion here (above sketch)?

Further applications of Newton's third law

i) When swimming, the swimmer pushes the water backwards with his/her hands, and the water then pushes the swimmer forward.

ii) 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.

iii) 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.

Properties of action-reaction pairs

- They act simultaneously.
- They act on different objects.
- They are equal in magnitude.
- They act in opposite directions.

Newton's law of Universal Gravitation

Every particle in the universe attracts every other particle with a gravitational force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

In a form of an equation, the law is written as:

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

QUANTITY NAME	QUANTITY SYMBOL	UNIT NAME	UNIT SYMBOL
Force	F	Newton	N
Gravitational constant	G	Newton metre squared per kilogram squared	Nm^2kg^{-2}
Mass	m	kilogram	kg
Distance	d	metres	m

Weight

Weight is the gravitational force the earth exerts on any object on or near its surface.

Weight can be calculated using the formula: **W = mg**

QUANTITY NAME	QUANTITY SYMBOL	UNIT NAME	UNIT SYMBOL
Weight	W	Newton	N
Mass	M	kilogram	kg
Gravitational acceleration	G	Metres per second squared	ms^{-2}

The value of **g is 9.8 ms^{-2}**

Acceleration due to gravity on earth can be calculated using the formula

$$g_{earth} = \frac{GM_{earth}}{r^2}$$

$$F = mg = \frac{GmM}{r^2}$$

(M_{earth} = 5.97219x10^{24}kg, $radius_{earth}$ = 6 378.1km)

Note: The same formula can be used to calculate g on any planet using the appropriate planetary data. Weight is force and therefore a vector quantity and mass is a scalar quantity.

Weight is measured in Newtons and mass is measured in kilograms.

EXAMPLE

Gravitational force exists between the sun and the Earth.

1.1 State Newton's law of Universal Gravitation in words. **2**

1.2 The mass of the sun is 330 000 times greater than that of the Earth. The distance between the centres of the sun and the Earth is 1,38 x 10^9 m. Calculate the gravitational force that the sun exerts on the Earth. **4**

1.3 How will the gravitational force that the Earth exerts on the Sun compare to the answer to QUESTION 5.2? Write only GREATER THAN, LESS THAN OR EQUAL TO. Give a reason for the answer. **2**

SOLUTIONS

1.1 Every body in the universe attracts every other body with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. **2**

1.2 $F = G\frac{m_1 m_2}{r^2}$ **OR** $F = G\frac{M_E m}{R_E{}^2}$ **4**

$$= 6,67\ 10^{-11} \times \frac{(5,98 \times 10^{24})[(330000)(5,98 \times 10^{24})]}{[1,38 \times 10^{9}]^2}$$

$= 4,13(3) \times 10^{26}$ N

1.3 Equal to **2**
Newton's third law is obeyed

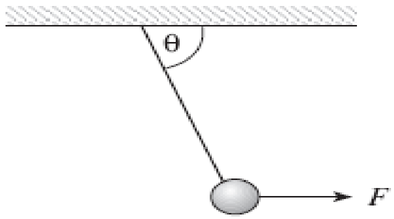
Newton's Laws Activities

Activity 1

A 5 kg mass is suspended by a rope. A horizontally directed force *F* is applied to the mass.

The magnitude of force is needed to produce an angle of 65° is _____N.

A. 21
B. 23
C. 44
D. 110



Activity 2

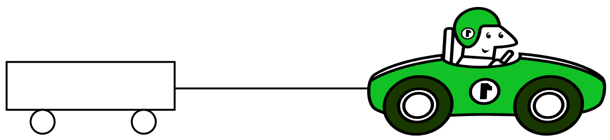
2 A motorist is travelling at 30 $m \cdot s^{-1}$ when he sees a tree lying across his path.
He brakes suddenly and the car comes to rest in 3,3 s.

2.1 Explain what happens to the driver in the car.

2.2 **Name and state** the law used to explain this phenomenon.

Activity 3

3 A car tows a trolley with the aid of a strong cable over a flat surfaced road. The system is accelerated at a rate of $4ms^{-2}$. The trolley experiences a frictional force of 1N.



M_2 = 880 kg m_1 = 900 kg

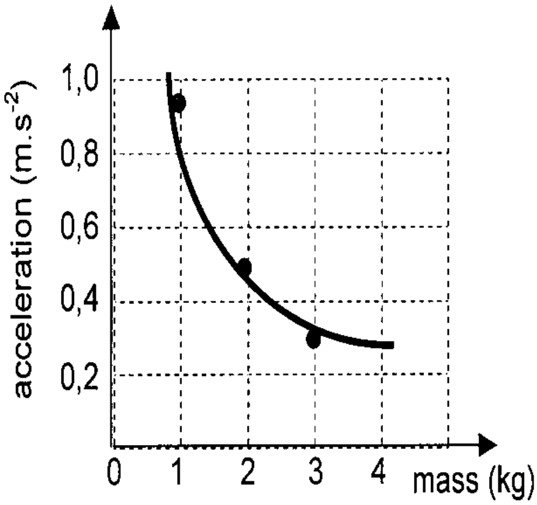
3.1 . Draw all the forces acting on the trolley and name them.

3.2 Determine the tension (T) in the cable

3.3 How will the magnitude of T be affected if the friction on the trolley is increased?

Activity 4

Learners are given the task of determining the relationship between the acceleration produced and the mass of a body. The learners then completed the above task and obtained the following results:



Mass of trolleys (kg)	Acceleration ($m.s^{-2}$)
1	0,96
2	0,49
3	0,31

4.1 In order to make the relationship between acceleration and mass more obvious, one would prefer a **straight line** graph.

4.2 Draw the a vs $\frac{1}{m}$ graph showing all working on how the values were obtained.

4.3 Determine the gradient of the graph.

4.4 What physical quantity does the gradient of the graph represent?

Activity 5

5.1 Two science learners, Steve and Charles, are doing experiments to verify Newton's Second Law. They accelerate a trolley, attached to a ticker timer and a ticker tape, along a horizontal surface. They measure the accelerating force by means of a spring balance, which they have attached to the trolley. They do several runs with the trolley, each time increasing the applied force. They record their results:

Trolley

Ticker timer

FORCE (N)	ACCELERATION ($m\cdot s^{-2}$)
5	0,600
4	0,455
3	0,315
2	0,175
1	0,035

5.1.1 Use their results and plot a graph of Force versus Acceleration.

5.1.2 Explain the position of the intercept of the graph on the x-axis.

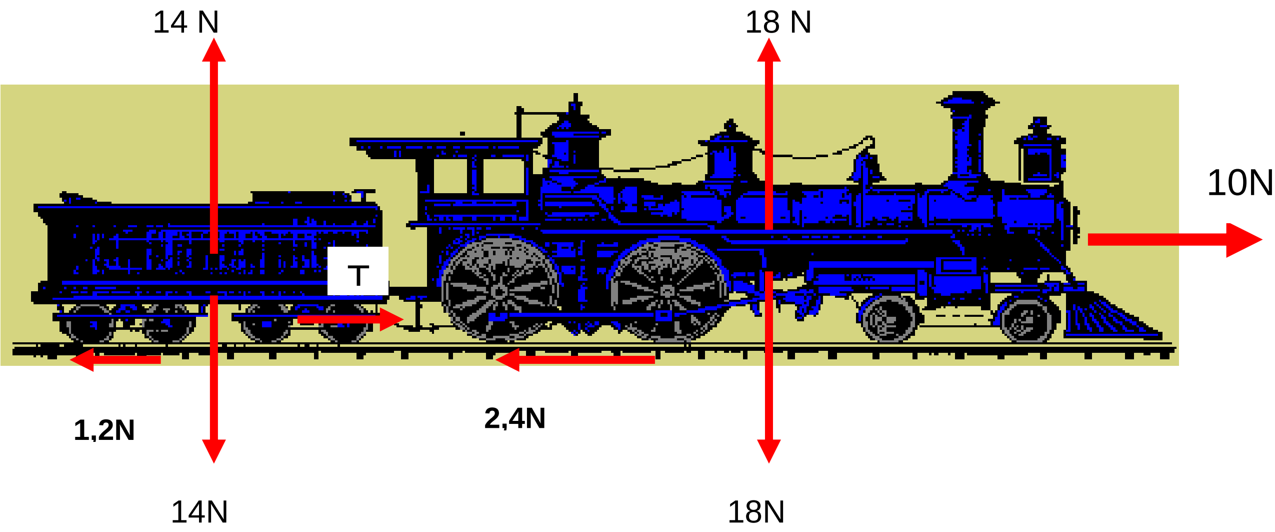
5.1.3 Use the graph to determine the mass of the trolley.

5.1.4 If the experiment was repeated by using the same trolley on a much **smoother** surface, how would a graph obtained from such an experiment differ from the graph obtained from the experiment done by Steve and Charles?

5.2 A little boy plays with his toy train. He ties the engine to the first truck of the train, using a piece of string. He ties a second piece of string to the engine. He pulls the train to the right on a horizontal surface, with a force of 10 N.

The masses of the engine and the truck are 1,8 kg and 1,4 kg respectively.

Frictional force of 2,4 N acts between the engine and the surface and a frictional force of 1,2 N acts between the truck and the surface.



5.2.1 Draw two separate, labelled free-body diagrams, indicating all the forces acting on the truck and on the engine.

5.2.2 Calculate the acceleration of the train

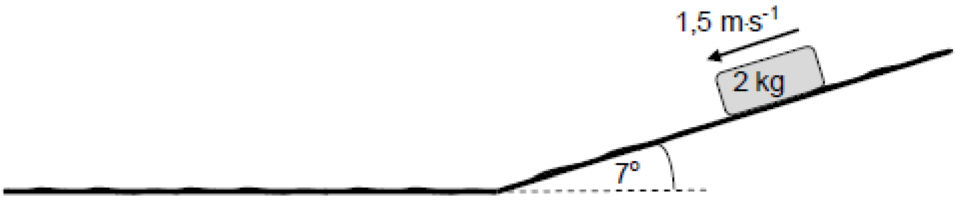
5.2.3 Calculate the force that the engine exerts on the truck.

5.2.4 Calculate the coefficient of static friction for the engine on the surface.

5.3 A force F acts on a body and the body accelerates. If the mass of the body is doubled and the force is halved, how would the acceleration of the body be affected? Write down ONLY increased, decreased or remain the same.

ACTIVITY 6

In the diagram below, a small object of mass 2 kg is sliding *at a constant velocity* of 1,5 m·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.*

6.1 Write down the magnitude of the net force acting on the object. **1**

6.2 Draw a labelled free-body diagram for the object while it is on the inclined plane. **3**

6.3 Calculate the:

6.3.1 Magnitude of the frictional force acting on the object while it is sliding down the inclined plane **3**

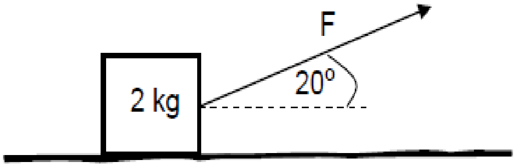
6.3.2 Coefficient of kinetic friction between the object and the surfaces **3**

6.3.3 Distance the object travels on the horizontal surface before it comes to a stop **5**

ACTIVITY 7

7.1 A crate of mass 2 kg is being pulled to the right across a *rough* horizontal surface by a constant force F.

The force F is applied at an angle of 20° to the horizontal, as shown in the diagram below.



7.1.1 Draw a labelled free-body diagram showing ALL the forces acting on the crate.

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.

Calculate the magnitude of the:

7.1.2 Normal force acting on the crate

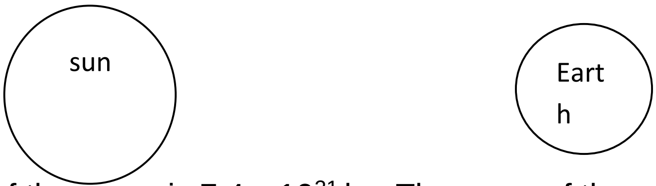
7.1.3 Force F

7.1.4 Acceleration of the crate

ACTIVITY 8

8.1 A space capsule of mass 300 kg lands on a planet that has a mass twice that of Earth, and a radius three times that of Earth. Calculate the weight of the space capsule on this planet.

8.2



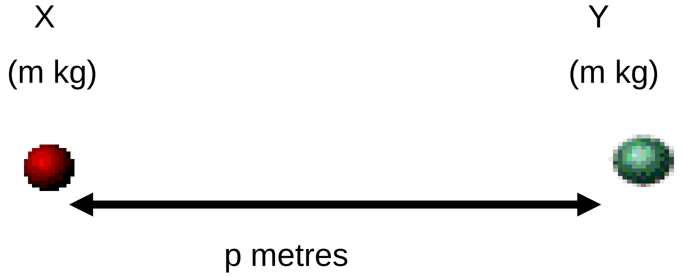
The mass of the moon is 7.4×10^{21} kg. The mass of the sun is 1.98×10^{30} kg. The centre of the moon is an average distance of 3.8×10^{8} m from the surface of the Earth

8.2.1 State Newton's Law of Universal Gravitation.

8.2.2 Calculate the magnitude of the gravitational force that the moon would exert on the bucket of water of 10kg on Earth.

ACTIVITY 9

9.1 Two asteroids, X and Y, are in outer space. Their centres are p metres apart. Each has a mass of m kg. A gravitational force F exists between X and Y.



By what factor would F change when:

i) the mass of X is doubled; and then

ii) the distance between X and Y is decreased to ⅓ of the original?

9.2 The sun exerts an average force of $3,57 \times 10^{22}$ N on the earth.

9.2.1 What force does the earth exert on the sun?

9.2.2 Calculate the mass of the sun. Take the mass of the earth as 6×10^{24} kg and the average distance between the centre of the earth and the sun as $1,5 \times 10^{8}$ km

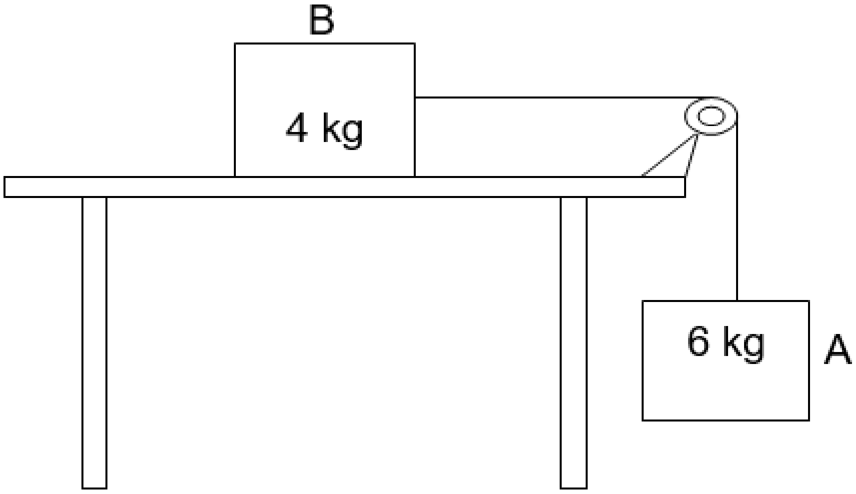
9.3 A learner makes the following statement:

Two rocks fall from the same height above the earth. The first rock has twice the mass of the second rock. The first rock will fall with double the acceleration of the second rock.

- Evaluate this statement.
- Is it true or false?
- Explain your answer.
- Include a formula derived from Newton's Laws, to prove your answer.

ACTIVITIES (PAST EXAMINATION PAPERS)
QUESTION 1 (EASTERN CAPE 2016)

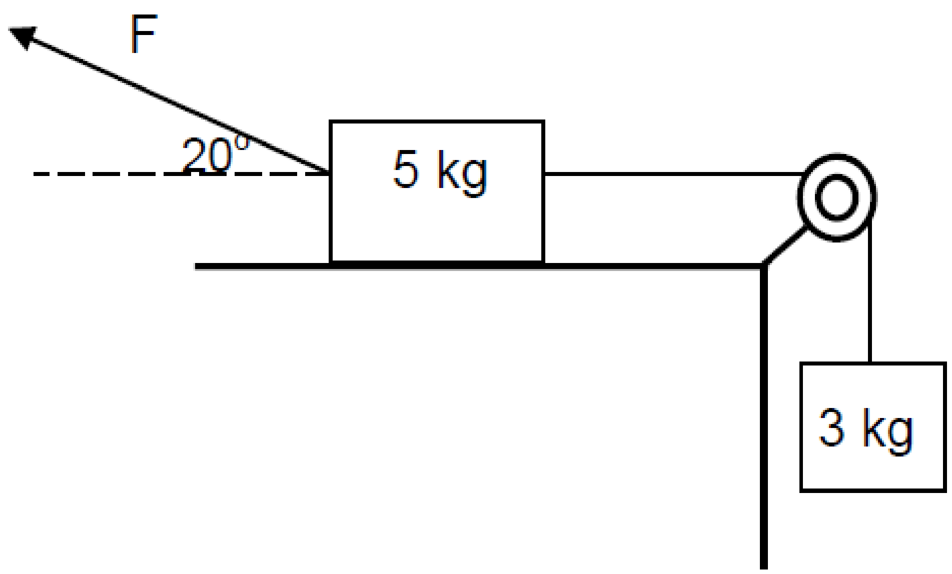
A 4 kg block B, resting on a flat, rough horizontal table, is connected by a light inextensible string to a 6 kg block A. The string is passed over a light frictionless pulley in such a way that block A hangs vertically downwards as shown in the diagram below.



1.1	Write down Newton's Second Law of motion in words.	**2**
1.2	Draw a free-body diagram of all forces acting on block B.	**4**
1.3	The kinetic frictional force experienced by block B is 32,53 N to the left. Calculate the magnitude of the acceleration.	**6**
1.4	Calculate the coefficient of kinetic friction between the surface of the table and block B.	**3**
1.5	How will the frictional force on the block be affected if the 4 kg block is pulled at an angle of 30° to the horizontal? Write down INCREASE; DECREASE or REMAIN THE SAME. Explain your answer.	**3**

QUESTION 2 (FREE STATE PRELIM 2016)

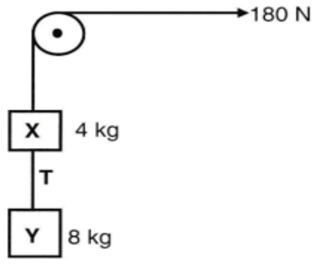
A 5 kg block, resting on a rough horizontal surface, is connected by a light inextensible string passing over a light frictionless pulley to a second block of mass 3 kg hanging vertically.
An applied force **F** is acting on the 5 kg block as shown in the diagram below and the coefficient of kinetic friction between the 5 kg block and the surface is 0,2.
The 5 kg block accelerates to the left.



2.1	Define the term frictional force.	**2**
2.2	Calculate the magnitude of the:	
2.2.1	Vertical component of F if the magnitude of the horizontal component of F equals 38 N	**2**
2.2.2	Normal force acting on the 5 kg block	**3**
2.3	State Newton's Second Law of motion.	**2**
2.4	Draw a labeled free-body diagram to indicate all the forces acting on the 3 kg block.	**2**
2.5	Calculate the magnitude of the tension in the string connecting the two blocks.	**6**

QUESTION 3 GAUTENG PRELIM 2016

Block X of mass 4 kg is connected to block Y of mass 8 kg by a light, inextensible string. Another light, inextensible string attached to block X runs over a frictionless pulley. The system is pulled by means of a constant force of 180 N as shown in the diagram below. Ignore the effects of air resistance.



3.1 State Newton's second law of motion in words. 2

3.2 Draw alabelled free body diagram showing ALL the forces acting on object X. Calculate the: 3

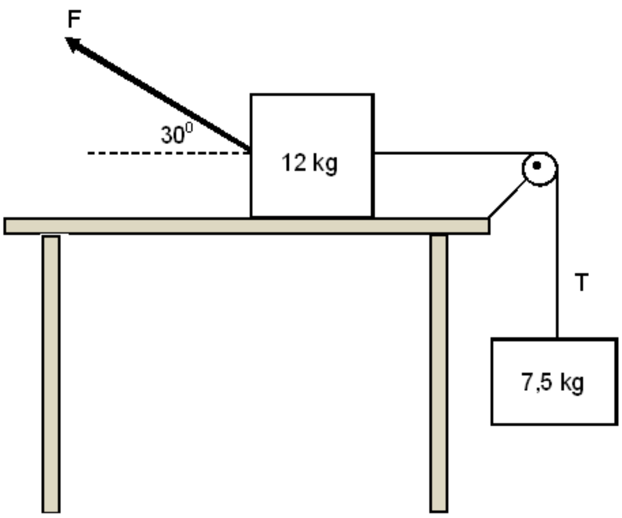
3.2.1 tension T in the string connecting the two blocks. 4

3.2.2 magnitude of the acceleration of block X. 2

QUESTION 4 (KZN PRELIM 2016)

4.1 Write down Newton's Second Law in words. 2

4.2 A block of mass 12 kg resting on a rough horizontal table is connected by a light inextensible string which passes over a frictionless pulley to another block of mass 7,5 kg. The 7,5 kg block hangs vertically as shown in the diagram below. A force of magnitude F is applied to the 12 kg block at angle of 30^0 to the horizontal to prevent the blocks from moving.



The maximum co-efficient of static friction(μ_s), between the 12 kg block and the surface of the table is 0,45. Ignore the effects of air friction.

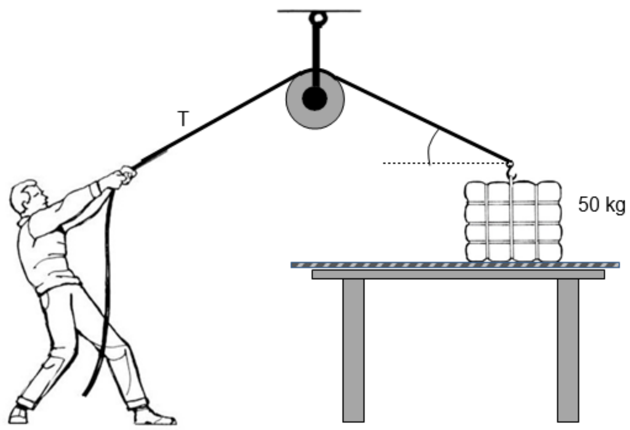
4.2.1 Calculate the tension, T, in the string. 2

4.2.2 Calculate the minimum value of F that will prevent the blocks from moving. 4

4.3 A satellite of mass 650 kg is in orbit around the Earth. The Earth exerts a force of magnitude 6346,07 N on the satellite. Calculate the height, in kilometres, of the satellite above the surface of the Earth. 5

QUESTION 5 (WESTERN CAPE PRELIM 2016)

A man applies a constant pulling force on a heavy parcel of mass 50 kg using a light inextensible rope which passes over a light frictionless pulley as shown in the diagram below. The coefficient of static friction between the parcel and the rough table surface is 0,34. The magnitude of the maximum static frictional force is 120 N. Ignore the mass of the rope.



5.1 Draw a free-body diagram showing all forces exerted on the parcel. 4

5.2 State, in words, *Newton's Second Law of Motion*. 2

5.3 When the static frictional force is at its maximum, show that the magnitude of the vertical component of the tension force in the rope is 137,06 N. 5

5.4 Hence, determine the angle (ϴ) that the rope forms with the horizontal as well as the magnitude of the tension force in the rope (T). 4

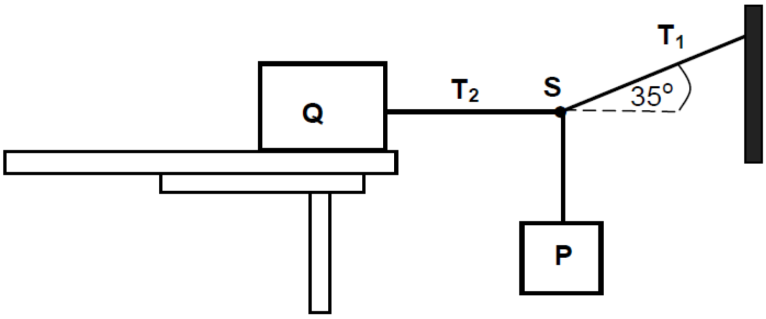
5.5 The man now increases the magnitude of his pulling force. Under the action of
this new constant force, the parcel begins to slide horizontally along the table.

5.5.1 How will the magnitude of the normal force change as the parcel slides across the table surface? State only INCREASES, DECREASES or REMAINS THE SAME. 1

5.5.2 Give a reason for your answer to QUESTION 5.5.1. 2

QUESTION 6 (GRADE 11NOVEMBER 2014)

A block **Q** of mass 70 kg is at rest on a table. It is connected to block **P** by means of two light inextensible strings knotted at **S**. A third string is arranged in such a way that the string connecting block **Q** is **horizontal** as shown in the diagram below. The coefficient of static friction between block **Q** and the surface of the table is 0,25. The knot **S** is in equilibrium.



The tension in the string connecting block **Q** is T2 and that for the string that pulls at 35° is T1 as shown in the diagram.

6.1 Define the term *static frictional force* in words. (2)

6.2 Explain what is meant by *the knot S is in equilibrium.* (2)

6.3 Draw a labelled free-body diagram to show all the forces acting on:

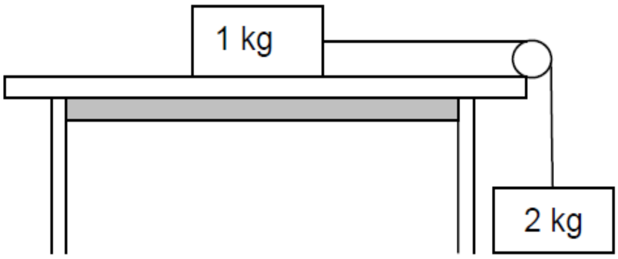
  6.3.1 The knot at **S** (3)

  6.3.2 Block **Q** (4)

6.4 Calculate the maximum weight of block **P** for which block **Q** will just begin to slip. (7)

QUESTION 7 (GRADE 11 EXEMPLER 2013)

In the diagram below, a 1 kg mass on a rough horizontal surface is joined to a 2 kg mass by a light, inextensible string running over a frictionless pulley. The coefficient of kinetic friction between the 1 kg mass and the surface is 0,13.



7.1 State Newton's second law of motion in words. 2

7.2 Calculate the magnitude of the:

7.2.1 Kinetic frictional force acting on the 1 kg mass 3

7.2.2 Acceleration of the 1 kg mass 5

The rough horizontal surface is now replaced with a smooth frictionless surface. The 2 kg mass is again released and strikes the ground before the 1 kg mass reaches the end of the horizontal surface.

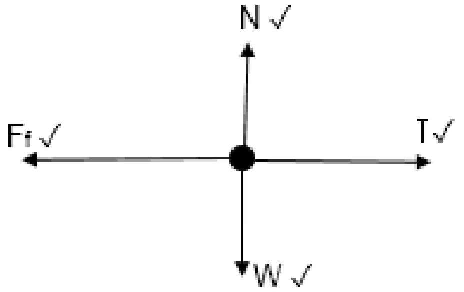
7.3 Will the 1 kg mass move at a LOWER, a HIGHER or a ZERO ACCELERATION? 4
Briefly explain the answer by referring to Newton's laws of motion.

Solutions to Newton's Laws Activities

QUESTION 1 (EASTERN CAPE 2016)

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

1.2



1.3 **On *6 kg:***

Fnet = ma ✓

Fg + (-T) = ma

(6 × 9,8) ✓ − T = 6 × a

58,8 − T = 6a

T = 58,8 − 6a (1)

On*4 kg*:

Fnet = ma ✓ any one

(-f) + T = ma

(-32,53) ✓ + T = 4 × a

T = 32,53 + 4a (2)

(1) - (2): 0 = (58,8 − 6a) − (32,53 + 4a) ✓

a = 2,63 m·s-2 ✓ (6)

1.4 **Positive marking from QUESTION 2.3**

fk = fk N ✓ any one

fk = k mg

32,53 = μk × 4 × 9,8 ✓

μk = 0,83 ✓ (3)

1.5 DECREASE ✓

At an angle of 30° the tension force will have a component in the vertical direction ✓and the block will be slightly lifted up. The normal will decrease and friction is directly proportional normal. ✓ (3)

[18]

QUESTION 2 (FREE STATE PREP EXAM 2016)

2.1 It is the force that opposes the motion of an object ✓ and which acts parallel to the surface✓ (2)

2.2.1

tan 20^0 =F_V/F_H

F_V = (tan 20^0)(38) ✓

= 13,83 N ✓ (2)

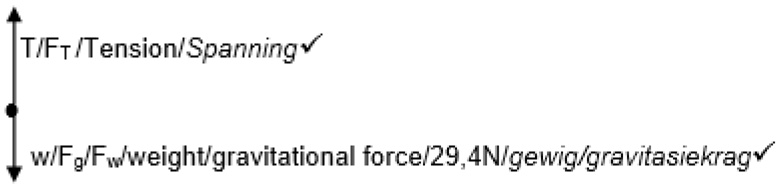
2.2.2 FN = Fg - Fv

= (5)(9,8) ✓ - 13,83 ✓

= 35,17 N ✓ (3)

2.3 When a resultant force acts on an object the object will accelerate in the direction of the force at acceleration directly proportional to the force ✓ and inversely proportional to the mass of the object. ✓ (2)

2.4



(2)

2.5 **Option 1**

Left/upwards as positive:

5 kg block: F_{net} = ma ✓

-T + FH - f = ma

-T + 38 - (0,2)(35,17) ✓ = 5a ✓ (1)

3 kg block : -Fg + T = ma

-(3)(9,8) + T = 3a ✓ (2)

Substitute 2 into 1:

a = 0,196 m·s-2

Substitute a into 2:

-29,4 + T = (3)(0,196) ✓

T = 29,99 N ✓

2.5 Option 2

Right/downwards as positive:

5 kg block: F_{net} = ma ✓

T - FH + f = ma

T - 38 + (0,2)(35,17) ✓ = -5a ✓ (1)

3 kg block : Fg - T = ma

(3)(9,8) - T = -3a ✓ (2)

Substitute 2 into 1:

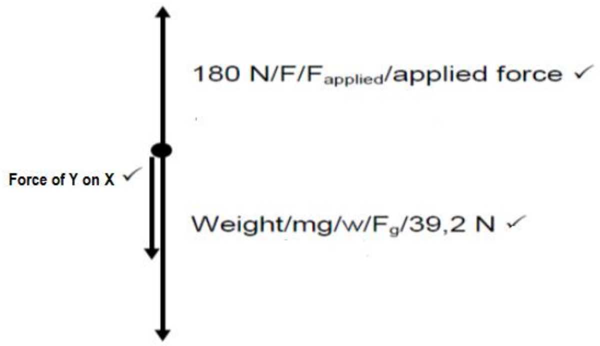
a = 0,196 m·s-2

Substitute a into 2:
29,4 - T = -(3)(0,196) ✓
T = 29,99 N ✓ (6)

QUESTION 3 (GAUTENG PREP EXAM 2016)

3.1 When a resultant/net force acts on an object, the object accelerates in the direction of the (net) force at an acceleration directly proportional to the force ✓ and inversely proportional to the mass of the object. ✓

3.2.



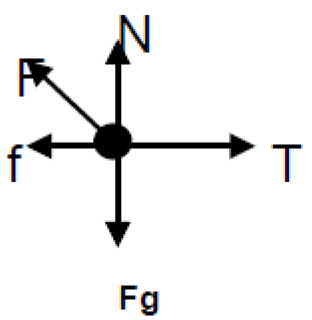
3.3
3.3.1
For block X
F_{net} = ma ✓
180 - w – T = ma
180 - (4)(9,8) – T = 4a ✓
140,8 – T = 4a ………………(i)
For block Y:
F_{net} = ma
T - w = ma
T - (8)(9,8) = 8a ✓
-78,4 +T = 8a……………….(ii)
281,6 – 2T = 8a
-78,4 + T = 8a
360 – 3T = 0
T = 120 N
T = 120 N upwards ✓
Note:
• If the system approach is used to first calculate acceleration and then acceleration is substituted to obtain T:
Max. 2/4 (4)
3.3.2
POSITIVE MARKING FROM QUESTION 3.3.1

OPTION 1
-78,4 +T = 8a
-78,4 + 120 = 8a ✓
a = 5,2 $m \cdot s^{-2}$ ✓
OPTION 2
140,8 – T = 4a
140,8 – 120 = 4a ✓
a = 5,2 $m \cdot s^{-2}$ ✓
OPTION 3
281,6 -2T = 8a
281,6 + 220 = 8a ✓
a = 5,2 $m \cdot s^{-2}$ ✓ (2)

QUESTION 4 (KZN PREP EXAM 2016)
4.1 When a resultant/net force acts on an object, the object will accelerate in the direction of the force. This acceleration is directly proportional to the net force ✓ and inversely proportional to the mass of the object. ✓ (2)

4.2.1 **For the 7,5 kg mass**
T - Fg = ma
T - (7,5)(9,8) = 0
T = 73,5 N (2)

4.2.2 **For the 12 kg mass**



F cos30^0 + f_f - T = ma
0,866 F + μ_sN - 73,5 = 0 ✓
0,866 F + 0,45(12)(9,8) ✓ - (0,45)F sin30^0 ✓ - 73,5 = 0
0,64 F + 52,92 - 73,5 = 0
F = 32,16 N ✓
(accept range: 32,106 – 32,16)
(4)

4.3 $F = \frac{Gm_1m_2}{r^2}$ ✓

6346,07 ✓= $\frac{6,67 \times 10^{-11} \times 5,98 \times 10^{24} \times 650}{(R+h)^2}$ ✓

R + h = 6391720,24 m

h= 6391720,24 – ✓$6,38 \times 10^6$

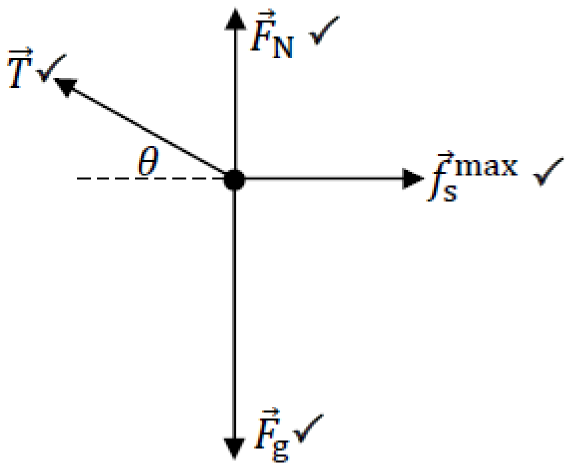
=11720,24m

=11,72 km ✓ (Range: 10,00km – 11,72 km)

(5)

QUESTION 5 (WESTERN CAPE METRO CENTRAL)

5.1



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

5.3 $f_s^{max} = \mu_s N$ ✓

120= (0,34) N ✓

N= 352,9412 N

Vertical forces; taking up as positive

$F_{net\ y} = 0$

$T_y + F_N + F_g = 0$ ✓

$T_y + F_N – mg = 0$

T_y + 352,9412 ✓– (50)(9,8) ✓=0

T_y= 137,06 N ……….(A)

5.4 Horizontal forces; taking left as positive

$F_{net\ x} = 0$

$T_x + f_s^{max} = 0$ ✓

T_x-120= 0

T_X =120 N ✓………………(B)

(A)/(B) :

$\tan\theta = \frac{137,06}{120}$

$= 1,14215$

θ= 48,80° ✓

Sub into (B) OR sub into (A)

T cos 48,8° =120

T= 182,18 N ✓

OR

T sin(48,8°) = 137,06

T = 182,16 N ✓ (4)

5.5.1 DECREASES ✓ (1)

5.5.2 From: T_y = T sin θ. The angle (θ) increases✓, so the vertical component of the tensional force (T_y) will increase ✓. OR

From: FN + Ty = Fg

θ increases/ Ty increases ✓

The parcel will not push as hard into the table surface ✓, so the normal force will decrease in magnitude. (2)

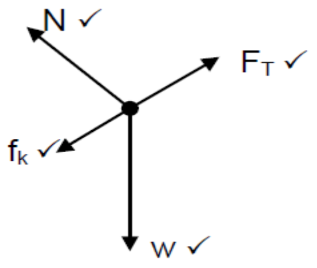
[18]

QUESTION 6 (NSC EXEMPLAR 2014)

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

6.2 Remains the same ✓ (1)

6.3



6.4

6.4.1Up the incline as positive:

$F_{net} = ma$

$F_T + f_k + w_{//} = ma$

$F_T + \mu_k N + w\sin30° = ma$

$F_T + \mu_k mg\cos30° + mg\sin30° = ma$ ✓Any one

$F_T – (0,2)(6)(9,8)\cos30°$✓ $- (6)(9,8)\sin30° = (6)(4)$ ✓

$\therefore F_T = 63,58$ N ✓ (5)

6.4.2 Up the incline as positive:

$F_{net} = ma$

$F + f_k(6 \text{ kg}) + f_k(3 \text{ kg}) + w_{//} = ma$

$F + \mu_k N(6 \text{ kg}) + \mu_k N(3 \text{ kg}) + mg\sin30° = ma$✓Any one

$F – (0,2)(6)(9,8)\cos30°$✓ $- (0,1)(3)(9,8)\cos30°$✓ $- (9)(9,8)\sin30°$✓ $= 0$ ✓

$\therefore F = 56,83$ N ✓ (6)

6.5 Decreases ✓ (1)

[19]

QUESTION 7 (NSC GRADE 11 2013 EXEMPLAR)

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

7.2

7.2.1 $f_k = \mu_k N$ ✓
$= (0,13)(1)(9,8)$ ✓
$= 1,27$ N ✓ (3)

7.2.2 For the 2 kg mass (to the right/downwards as positive):
$F_{net} = ma$ ✓
$w + F_T = ma$
$(2)(9,8) + F_T = 2a$✓
$F_T = 2a – 19,6$
For the 1 kg mass (to the right as positive):
$F_{net} = ma$
$F_T + f = ma$
$-(2a – 19,6) + (- 1,27)$✓ $= 1a$ ✓ $F_T(1\text{ kg}) = -F_T(2\text{ kg})$
$\therefore a = 6,11 \text{ m·s}^{-2}$ ✓ (5)

7.3 Zero acceleration.✓
F_{net} on the 1 kg mass is zero. ✓
According to Newton's second law of motion, its acceleration will be zero.✓
According to Newton's first law of motion, it will continue to move at constant velocity (until it reaches the edge of the surface). ✓ (4)

[14]